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JULY 1920

SOCIETY OF AUTOMOTIVE ENGINEERS INC.
29 WEST 39TH STREET NEW YORK

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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. VII July, 1920 No. 1

The Summer Meeting

THE Summer Meeting of 1920 has passed into history leaving a lasting impression of complete success upon the minds of all those members and guests who were fortunate enough to attend it. Ottawa Beach on the sandy shores of Lake Michigan played hostess in most acceptable fashion, the natives having become familiar during the summer of 1919 with the enthusiasm and activities of S. A. E. members on vacation. The weather prophet started in a way to indicate that he intended to dampen the spirit of the meeting, but after furnishing a typical blue and rainy Sunday became convinced that his direful intention could not be satisfied. During the rest of the week the sun shone in all its glory, and the meeting was the occasion of great recreational and sporting as well as technical interest.

This year it was necessary for the Society to charter practically all of the hotel accommodations within commuting distance of the headquarters at Ottawa Beach. Hotels Ottawa, Waukazoo and Grand were filled to capacity throughout the entire week, and Hotel Macatawa was obliged to handle a considerable overflow. The registration records show that there were actually 750 members and guests who availed themselves of the opportunity to spend an enjoyable meeting-vacation among their fellow members of the profession. It was evident that the attendance was very representative, not only geographically but from the standpoint of the various automotive engineering fields. The marine and the tractor men exchanged opinions and smiles with their fellows of the automobile, the airplane and the stationary engine industries; and, of course, the fraternity of the accessory and parts business were on hand.

THE HOTEL OTTAWA WHERE THE MEETING WAS HELD

A BASEBALL GAME ON THE HOTEL LAWN

SPORTS

The sports program was one of the outstanding features of the meeting. It was directed by Harry Knepper of Detroit with the aid of an active corps of assistants. The golf tournament, under the supervision of Howard A. Coffin, started on Monday afternoon with a field of sixty-six entrants, testifying to the popularity of this mode of recreation among automotive men. For the benefit of those not able to qualify for the finals a consolation flag tourney was run on Wednesday. This was captured by Malcolm Robertson. The final round played on Thursday afternoon was completed with A. S. Norris at the top of the list. H. A. Coffin won the driving contest. The tennis tournament comprising singles and doubles was handled by Harold W. Slauson. This tournament, second only to golf in popularity, found twenty-nine members ready to dispute the singles championship and twelve teams eager to prove their superiority in the doubles. After many heated matches, the singles narrowed down to a final match between H. M. Crane and C. F. Clarkson, won by the latter. Playing together they won the doubles event, defeating C. F. Scott and Harold W. Slauson. The most successful contest in the sports program, measured by vociferous enthusiasm, was

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the soft or indoor baseball series between teams representing Metropolitan, Cleveland, Mid-West and Detroit Sections. The Metropolitan Section was first eliminated by Mid-West, and on Wednesday it in turn was defeated by Cleveland who had previously won from Detroit. The score of the final game for the championship was 6 to 2. This game which was very well played proved to be one of intense interest. The spectators at times reached the point of excitement where it appeared that the entire assemblage of fans would participate in the game. It was completed without casualties, however. Cleveland has now won the cup for this series twice, and according to predictions of the representatives of our fifth city no anxiety need be felt over the result of next summer's contest. The games were played in the afternoon on the lawn in front of the hotel, offering the ladies an excellent chance to display the very latest things in sport wear, and they made the most of it.

The handsome new trophy for the outdoor baseball championship was won by the Metropolitan Section. The games in this series were played on the side of Black Lake opposite the Hotel Ottawa, and due to the difficulty in reaching the field were not attended by many. It is generally understood that this was not disappointing to the contestants, however, for there is some question as to the quality of entertainment that was provided, and it is rumored that many athletes became definitely acquainted with their limitations. It is just as well that the scores be retained in the memories of the participants, but as a matter of interest it may be said that Mid-West defeated Indiana on Wednesday, Metropolitan defeated Cleveland on Thursday, and Mid-West defaulted to Metropolitan in the final game. Both baseball series were directed by George Hunt.

The races and field events were grouped together on Wednesday afternoon, an athletic field having been laid out on the lawn at the Hotel Ottawa. For the conduct of this day of sport the committee deserves particular commendation. The field was properly roped off, so that all could see, and the usual tedious wait between events was eliminated by the systematic despatch of all starters. Without exception each event brought out very interesting and close competition, and those who won the prizes can feel that they were earned only by superior ability. It was surprising to see the number of heavy-weight engineers that were uncovered for participation in the tug-of-war. This event was won by Cleveland after defeating first Philadelphia and then Detroit.

The following summary not only lists the events but includes the names of the prize winners.

50-yd. Dash, men under 28; first, D. W. Jones, 5½ sec.; second, M. P. Whitney; third, W. H. Fleming
50-yd. Dash, men 28 to 35; first, L. E. Joseph, 6½ sec.; second, D. R. Swinton; third, W. G. Gernandt
50-yd. Dash, men over 35; first, H. P. Macdonald, 7 sec.; second, S. P. Hess; third, Mark A. Smith
40-yd. Dash, ladies under 25; first, Miss E. L. Beamer, 5 sec.; second, Miss E. M. Dorris; third, Miss Douglas
40-yd. Dash, ladies over 25; first Mrs E. Dickey, 5 2/5 sec.; second, Mrs. H. G. Wilson; third, Mrs. H. G. Welfare
Shot Put; first, H. E. Kirby, 15 ft. 11 in.; second, H. P. Macdonald; third, I. S. Snead
High Jump; first, B. W. Brodt, 4 ft. 11¼ in.; second, W. S. Wolfe; third, D. H. Torrey
Fat Men's Race, 200 lb.; first, C. A. Chambers, 5 sec.; second, A. K. Brumbaugh; third, H. G. Welfare
Plump Ladies Race; first, Mrs. H. A. Coffin, 4 1-5 sec.; second, Mrs. F. D. Heath; third, Mrs. E. W. Temple
Potato Race, men; first, E. O. Jones, 1 min. 44 3-5 sec.; second, R. H. Upson; third, T. M. Franzen
Potato Race, ladies; first, Mrs. C. Douglas; second Mrs. E. Dickey; third Miss E. L. Beamer
Hop, Skip and Jump; first, L. E. Joseph, 34 ft. 6 in.; second, M. P. Whitney; third, H. Schlachter
Three-Legged Race; first, E. L. Jones, D. R. Swinton; second, H. C. Snow, A. D. T. Libby; third, M. A. Smith, L. Switzer
Egg Race, ladies; first, Miss E. L. Beamer; second, Mrs. H. G. Wilson; third, Miss E. M. Dorris
Standing Broad Jump; first, H. Schlachter, 10 ft. 2 in.; second, O. C. Berry; third, L. E. Joseph
Running Broad Jump; first, L. E. Joseph, 17 ft. 3½ in.; second, M. P. Whitney; third, H. Schlachter
Throwing Baseball, ladies; first, Mrs. H. G. Welfare, 100 ft.; second, Mrs. L. M. Spillman; third, Mrs. G. D. Harris; fourth, Mrs. C. E. Hawke
50-yd. Dash, boys; first, Bob Jardine; second, Preston Dorris; third, Donald Leenhouts

The general announcements, ladies sports, cards and dancing were handled by Howard L. Spohn in a manner that excited much favorable comment. Nearly all of the ladies' contests occurred in the morning, when the men were busy in the technical sessions. The croquet tournament proved very popular, and the games were watched by large galleries daily. Mrs. H. A. Coffin won the singles and with Mrs. H. T. Ewald further proved her prowess by winning the doubles. The clock golf tournament for ladies disclosed a dark horse in the person of Mrs. J. G. Vincent. There were two card tournaments, bridge and 500, being won respectively by Mrs. C. R. Baker and Mrs. Edward O. Spillman.

The water sports were run off on Thursday afternoon and were greatly enjoyed by large numbers seated on the wharf in front of the hotel. The most amusing event was of course the tilting contest, but from the experience of some of the contestants this was true from the standpoint of the spectators only; the waters of Lake Michigan had not warmed up to the occasion. The following is a summary of the aquatic events, with the winners:

25-yd. Swim; first, W. H. Miller; second, N. MacCoull; A. J. Langhammer disqualified for fouling
25-yd. Breast Stroke; first, A. J. Langhammer; second, R. H. Upson; third, N. MacCoull
Plunge for Distance; first, Ira S. Snead; second, N. MacCoull
Diving for Form; first, Sandy Brown, 49 points; second, W. H. Shultz, 43 points
Distance Swim; first, A. J. Langhammer; second, W. H. Miller; third, N. MacCoull
Canoe Singles; first, Jack Grary; second, N. MacCoull
Canoe Doubles; won by C. Griffin and H. P. MacDonald
Canoe Tilting; won by Langhammer and Warren

Trapshooting followers had a keen competition on Thursday, reducing to atoms many hundreds of mythical birds. W. H. Miller proved his ability to draw straight lines as engineers should draw them and captured the prize in this event. The quoits contest developed W. H. Pratt as the star ringer.

During all of the sports program, on Wednesday and Thursday, the forty-piece band of the Continental Motors Co., of Muskegon, entertained the spectators. In the evenings at dinner, the band rendered a formal concert, and its music was greatly appreciated.

Each evening after the lecture the motion-picture machine on the porch vied for popularity with the syncopating orchestra in the ball-room. The screen presented to the members such personalities as Charlie Chaplin, Charles Ray, Constance Talmadge and Elsie Janis. It must be admitted that the gentleman of the cane and derby won the contest for the favorite star. On Thursday evening a very entertaining and instructive film of the steel industry was exhibited and highly praised. As noted, the films and dancing were in competition, but both had many adherents and were very much appreciated. The dancing reached its climax on Thursday evening, when the Grand Ball was the feature. This occasion gave the ladies further opportunity to display the latest products of the costumer, and the colorful result will not be forgotten. The S. A. E. dancing trophy, which is competed for yearly at the Summer Meetings, was won by Mrs. Robert W. Carrington, who was ably assisted by D. W. Bay. Little Miss Daphne Gibson entertained the ball patrons with a very sweet dance number as an old-fashioned colonial miss and was roundly

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B. B. Bachman
David Beecroft

Dr. H. C. Dickinson
H. M. Crane
W. E. Lay

applauded. The dancers continued their revelry until the wee hours of the morning.

Mention must be made of the very fine character of the prizes that rewarded the victors in the many events. Through the generosity of a large number of companies directly engaged in the automotive industry, the committee was able to eclipse all past prize appropriations, and the money was expended with great care.

The rivalry between the Sections was well demonstrated by their efforts to outdo one another in stunts. The Mid-West Section presented as its offering prize fights in two bouts. The first, by far the most entertaining, was between two members of the Section whose abilities as comedians outshone any fistic skill displayed. The second bout however was of a more businesslike character, between professionals, with a little local color added by the Section seconds. The Metropolitan Section conducted a test of a tank recently invented by them, the internals of the apparatus being very mysterious. It was finally determined that it was operated by manpower, after confidential consultation with the prominent gentleman who proved brave enough to explain the evolution to the audience. The Pennsylvania Section exhibited two things, one of which proved to be a great dragon, the identity of the other being somewhat doubtful though of distinctly Turkish origin.

Standards Committee Report

The current reports of the Standards Committee Divisions, mailed to the members in pamphlet form recently, were approved by the Standards Committee and the Council and at the Society meeting, for submission to letter ballot of the voting members, except in the following respects:

The recommendation by the Electric Transportation Division of a definition of the front end of an industrial truck or tractor was referred back. The recommendation of the same Division as to the use of the term "clearance radius" was amended to include inside clearance radius. The Division withdrew its recommendation as to type of resistance to be used for industrial trucks and tractors. In the report of the Tire and Rim Division the wedge-ring specifications were eliminated.

Presidential Address

President Vincent's address, which was very well received, was divided into two parts covering Society and organization matters and a review of some of the problems confronting the automotive industry. The problems which he stressed were those relating to the banking policy instituted by the Federal Reserve Board in restricting credits; a study and investigation of highway transportation and the decline of the fuel reserve.

Treasurer's Report

The report of the Treasurer showed that the total assets of the Society were $202,844.19 on June 1, with accounts payable of $15,989.33; that the income of the Society for the first eight months of the current fiscal year beginning Oct. 1, 1919, was $168,859.23, this being $25,848.91 in excess of expenses for the same period.

Membership Growth

Gratifying information was submitted on behalf of the Membership Committee to the effect that 590 applications for membership had been received since the first of the year, the total number, including affiliate member representatives and enrolled students being on June 1, 4869. Over 200 applicants for membership were approved at the Council meeting held last month. At the same time it became necessary to drop over 100 members for non-payment of dues, owing to a long list of delinquents that grew during the war in view of the liberal attitude of the Council. Aside from these, practically no members have been dropped for some years for non-payment of dues. The Society will have over 5000 members before the end of the calendar year. Of the 398 applications received since April 1, 248 were attributable to the work of the Membership Committee.

Nomination of 1921 Officers

David Beecroft was nominated to serve as President of the Society next calendar year, by the Nominating Committee which was completed and organized at the Ottawa Beach meeting. The committee reported the following other consenting nominees for the elective offices next falling vacant under the Constitution, i.e., after the 1921 Annual Meeting of the Society:

First Vice-president, H. L. Horning
Second Vice-president, representing motor-car engineering, B. B. Bachman
Second Vice-president, representing tractor engineering, E. A. Johnston
Second Vice-president, representing aeronautic engineering, H. M. Crane
Second Vice-president, representing marine engineering, Joseph Van Blerck
Second Vice-president, representing stationary internal-combustion engineering, T. C. Menges
Councilors (to serve during 1921 and 1922), W. A. Brush, F. W. Davis and D. L. Gallup
Treasurer, C. B. Whittelsey

The members of the 1920 Council who will hold over during 1921 are J. G. Vincent, as past-president, and Councilors E. A. De Waters, F. M. Germane and N. B. Pope.

The 1920 Nominating Committee was constituted of N. B. Pope (chairman), Metropolitan Section; H. R. Corse, Buffalo Section; Ernest Wooler, Cleveland Section; L. R. Smith, Indiana Section; B. B. Ayers, Mid-West Section; A. W. Scarratt, Minneapolis Section; A. K. Brumbaugh, Pennsylvania Section; V. G. Apple, G. P. Dorris and C. F. Scott, members at large, and W. B. Stout (secretary), Detroit Section.

Constitutional Amendments

The amendments to the Constitution of the Society submitted at its New York meeting in January were considered at Ottawa Beach, with the result that no changes were favored in the present Constitution except in the matter of the age under which persons can be admitted as Junior Members and the amount of junior membership annual dues. It was felt that the age mentioned should be raised from 26 to 30, and that the annual dues for Juniors should be $10. A letter ballot will accordingly be taken of the voting members of the Society on the adoption of the amendments to the Constitution indicated.

The sentiment of the meeting was expressed by resolution as strongly against compulsory adoption of the metric system.

Fuel Session

The interest taken in the Fuel Session, which was held on June 22, was so great that an adjourned meeting was held on the following afternoon. W. S. James of the Bureau of Standards presented results of tests made

SOME OF THE EXHIBITS

Goodyear Six-Wheel Truck
Farm Tractor Test
Dynamometer Test on Tractor
Dynamometer Test of Engine
International Harvester Dynamometer Car
New Tractor Gun
International Harvester Tractor
Dynamometer Used in Tractor Test

collaterally with the report of the Society committee on exhaust-heated devices for utilization of present fuels in currently produced engines.

O. H. Ensign gave a paper on Carburetion and Distribution of Low-Grade Fuels. H. M. Crane, Prof. C. A. Norman, W. E. Lay and P. S. Tice discussed points of engine design as affecting power output and fuel economy.

Secretary R. L. Welch of the American Petroleum Institute made the very important announcement that in his opinion enough gasoline of the grade now produced will be available during the next several years for use in automotive apparatus which it is predicted will be produced and running in, say, 1923. He placed great emphasis on the necessity of close cooperation of the automotive and the fuel industries to bring about this result.

Transportation Session

Several phases of transportation were taken up at the Transportation Session. G. A. Green, general manager and engineer of the Fifth Avenue Coach Co., prepared for the meeting a valuable paper on motor-bus operation. Brigadier-General C. B. Drake, chief of the Motor Transport Corps, U. S. A., transmitted for submission at the meeting a statement of the present opinions and policies of the Motor Transport Corps with regard to engineering development of motor transportation from the point of view of the problems and needs of the American Army. Col. E. S. Gorrell gave an interesting talk on air navigation, including points involved in international operations.

Chairman F. W. Davis, of the Society Committee on Science of Truck Operation, explained the work proposed to be conducted by this committee. Secretary H. G. Shirley of the Federal Highway Council presented an earnest argument for the construction of highways in an enduring way, stating that knowledge of the soils supporting roads is practically negligible, and that inasmuch as these are an essential factor of road maintenance, much study and investigation in regard to them is imperative. The members evinced a lively interest in the information on inland water transportation set forth by V. E. Lacy of Rochester and C. J. Baer of St. Louis.

Farm Power Session

E. A. Johnston, of the International Harvester Co., presided at the Farm Power Session. It is clear that farm machinery is to play a leading part in automotive engineering. Following his widely read paper presented at the recent meeting of the Society held in Kansas City, Major O. B. Zimmerman discussed at Ottawa Beach in an analytical way Fundamental Factors Affecting Tractor Design. Closely related to this paper was that of Percival White, Jr., on Operating Speeds of Agricultural Implements. The remarks at the session in this connection were enlivening. R. W. Lohman spoke on power farming from the standpoint of large operations.

Production Session

Taking up major items of the vital matter of production, the members devoted their attention in the concluding technical session of the meeting, with Harold Emmons presiding, to Production Control and Systems of Accounting by A. G. Drefs; The Workman as an Element in Production, by A. F. Knobloch; Interdepartmental Production Contests, by R. R. Potter, and other important industrial phases.

There had been collected for use at the session communications from many members of the Society giving opinions as to the most acute issues, the best things they had themselves accomplished recently and in what way they thought the Society could be of assistance.

Evening Lectures

The evening lectures were edifying, holding the attention of men, women and children. Frederick Palmer, the dean of war correspondents, described European conditions as seen by him on a recent trip, giving statesmanlike views on methods of alleviation of distress and fundamental points of government. Major T. H. Bane, Air Service, U. S. A., illustrated with slides and moving pictures in a very entertaining and instructive way recent advances in aviation. The motion pictures showing parachute jumping and the flying tank developed at McCook Field, were of particular interest. W. D. Shilts, chairman, board of control, Goodyear Tire & Rubber Co., lectured on the Economics of Present-Day Transportation Problems.

Exhibits

The exhibits at the meeting consisted of U. S. Army Ordnance automotive apparatus, farm tractors and implements and testing apparatus, automotive engines operated on heavy fuel and applied S. A. E. Standards. The Army Ordnance exhibit included tractor power cart, caterpillar hand cart, 2½-ton tractor, 75-mm. gun carriage and limber and the Mark VII self-propelled caterpillar mount for the 75-mm. gun, and the Christie wheeled caterpillar for 155-mm. gun. The tractor and implement demonstration equipment was dynamometer car, 8-16 tractor, 10-20 tractor, 5-ton caterpillar tractor, two-bottom plows, three-bottom plows, a speed plow and miscellaneous plow bottoms. The automotive-type engine operation on heavy fuel consisted of complete runs using separate intake and exhaust manifolds to demonstrate running qualities without the inlet-heating arrangement recommended by the committee of the Society; runs with hot-surface combination intake manifold and runs with special cylinder-heads to show their effects, including that of turbulence.

Plowing speeds with relation to plow draft in light soils comprised the major part of the tractor demonstration on one day. At other times comparative tests with gasoline, kerosene, distillate and high distillate were conducted; also tests to determine rolling resistance on various kinds of ground surface. Those interested in the plowing and Ordnance exhibits were transported from the boats by a six-wheeled truck with van body which was courteously furnished by the Goodyear Company.

The S. A. E. applied standards exhibit was a truck and tractor four-cylinder gasoline engine cut away and marked to show the location of many automotive parts and materials which have been standardized by the Society. There are 260 S. A. E. Standards, these applying to various automotive apparatus in the following respective numbers: Automobile, 168; truck, 129; isolated electric light plant and stationary gas engine, 82; motor boat, 62; motorcycle, 58; tractor, 53; aircraft, 50.

The *Daily S. A. E.* was published for the Society at the meeting by the United States Tire Co. The editors, E. S. Underhill and A. E. Hartzell, deserve mention for the success of the undertaking.

The meeting was a success. This success was attained by the energetic work of the Meetings Committee and the staff of the Society. This sketch would not be adequate without acknowledgment of their effort and conscientious devotion to a task whose magnitude is little appreciated by those not familiar with such work.

Analysis of Fundamental Factors Affecting Tractor Design

By OLIVER B. ZIMMERMAN[1] (*Non-Member*)

SEMI-ANNUAL MEETING PAPER *Illustrated with* CHARTS

THE farm tractor is finding itself among the most essential of mechanical agricultural devices; the industry is young, and the analysis of present-day products leaves us aware that controlling basic factors of design are not yet completely crystallized, nor has research had its proper share in the development. For this reason the following discussion will be of interest.

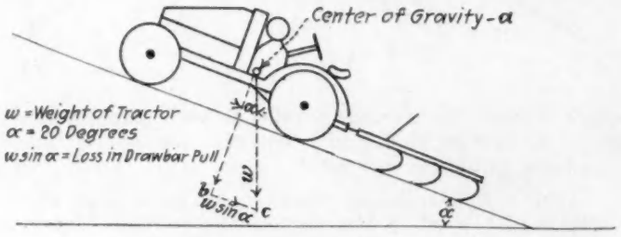


FIG. 1

Following up the discussion on Tractor Plowing Speeds, printed in the February issue of THE JOURNAL, some further factors will be discussed in this paper, inasmuch as they are basic and their nature and tendencies should be understood in their influence upon one another. For simplicity's sake the earlier article dealt chiefly with plowing data on the assumption that there was delivered at the drawbar of the tractor *a constant horsepower*, a condition which is not necessarily true for more than a narrow range of action, and then only under the ideal condition of level land and with the machine operating on perfect footing. We shall now start with a normal condition of *a constant engine power* which is to be delivered to the crankshaft under governor control for any of the travel speeds we are analyzing. The tractor will be considered as powered by a given brake-horsepower engine and this power will be transmitted through sets of gears in which the net bearing and gear efficiency is taken to be 73 per cent. The drawbar horsepower would then be theoretically the same for various weights of outfits which will be considered of equally good design and construction.

EFFECTS OF SLOPES AND WEIGHTS ON THE DRAWBAR PULL

As the available power of the engine is limited the influence of the slope as well as other losses of the tractor and equipment traveling at constant speed reflects itself in reducing the available drawbar pull. This can be analyzed by considering the combined weights of tractor and plows as being concentrated at some point. In Fig. 1, W = the weight in lb. and α = the angle of the slope in degrees; ab then is the component perpendicular to the slope and bc the component along the slope, the latter opposing the drawbar pull during ascent.

The net or available drawbar pull at any chosen speed equals drawbar pull possible on the level minus $W \sin \alpha$, or for any given speed we have the maximum slope angle found from $\sin \alpha = \frac{\text{Drawbar Pull at Speed Considered.}}{\text{Weight}}$

At this angle theoretically the tractor can just negotiate itself and the outfit.

Fig. 2 represents the result of various machines whose drawbar pulls are the same on the level, and compares relatively the various slopes theoretically possible to negotiate at various speeds, as well as the comparative speeds possible for any given slope. The friction angle of normal earths or the angle of repose of these soils is indicated between 14 and 45 deg. The limiting slopes which it is possible to negotiate practically are those of soil friction as well as that of the overturning effects of combined gravity and power drive. (See Fig. 14.) The latter is an important point in design and weight distribution. No slip is here considered. The curves on this diagram and others are carried higher than is practically possible, as well as to lower speeds than are desirable, in order to go beyond the normal range.

Fig. 3 illustrates the relation between speed and available drawbar pull on level ground, as well as the effect of a 10 and 20-deg. slope on the available drawbar pull and speed of an 8000-lb. outfit. With the different weight outfits the drawbar pull will be found constant for each when operating on the level. The 10 and 20-deg. slope curves will be more or less than those shown for the 8000-lb. outfit as determined by the relation of the factor $W \sin \alpha$ for each weight of outfit.

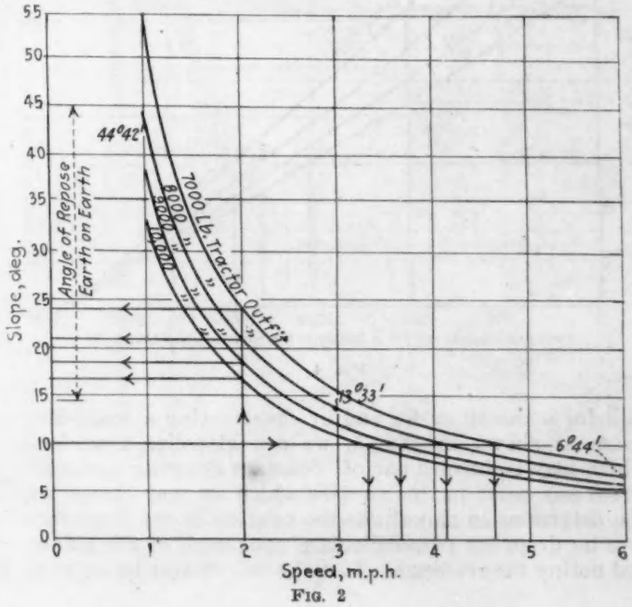


FIG. 2

[1]International Harvester Co., Chicago.

If we now analyze the relation of the available drawbar pull for the four weights of outfit at the same speed we are shown in Fig. 4, consisting of a series of radiating lines slightly dished toward the horizontal. At low angles of slope they approach straight lines. The relations of the effect of the various weights of outfit on

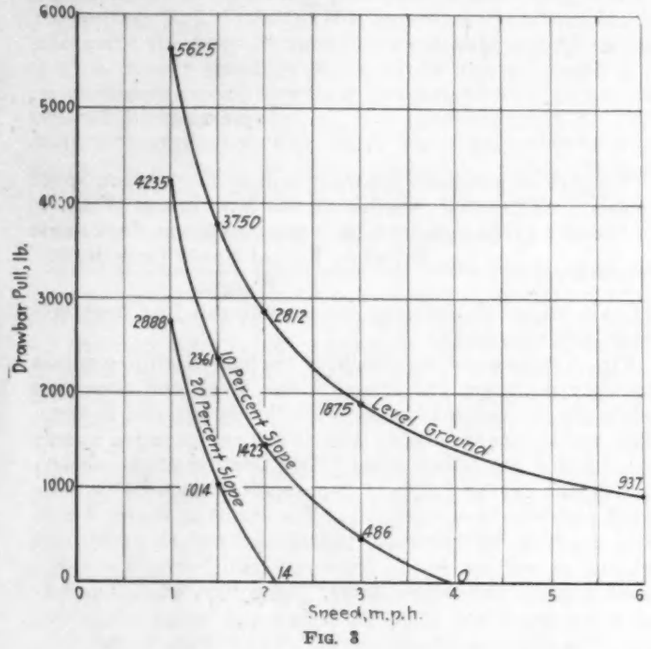


FIG. 3

the climbing angle and the effect on the drawbar pull of various weight outfits operating on a given slope can be read easily.

By combining in one diagram the relation of speed in miles per hour, climbing angle or slope and net drawbar

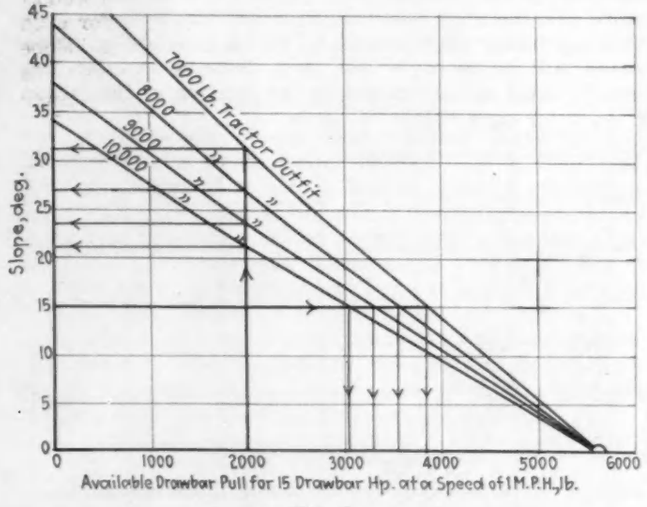


FIG. 4

pull for a chosen outfit, and by constructing a space diagram as shown in Fig. 5, we can visualize a surface which may be termed one of "constant drawbar surface." From any point in this surface which we may choose we can determine in magnitude the relation of the three factors by dropping perpendiculars upon each of the planes and noting the readings. To make this clearer let us pass

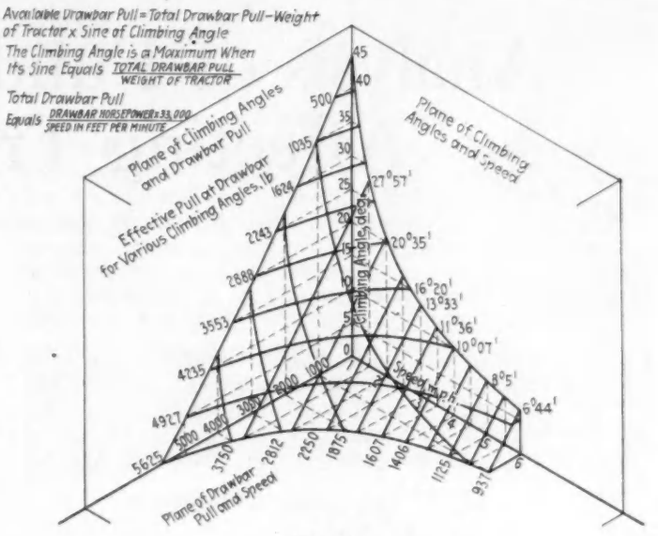

Available Drawbar Pull = Total Drawbar Pull − Weight of Tractor × Sine of Climbing Angle
The Climbing Angle is a Maximum When its Sine Equals TOTAL DRAWBAR PULL / WEIGHT OF TRACTOR
Total Drawbar Pull Equals DRAWBAR HORSEPOWER × 33,000 / SPEED IN FEET PER MINUTE
Plane of Climbing Angles and Drawbar Pull
Plane of Climbing Angles and Speed
Effective Pull at Drawbar for Various Climbing Angles, lb
Climbing Angle, deg.
Speed, m.p.h.
Plane of Drawbar Pull and Speed

FIG. 5

planes through the surface parallel to each plane in succession as in Figs. 6, 7, and 8, and note the record. Fig. 6 answers questions such as

With a 15-drawbar-hp. machine, and at a speed of 2½ m.p.h., what is the maximum theoretical slope angle at which an 8000-lb. outfit can negotiate itself? 16 deg. 20 min.

What is the net drawbar pull on the level? 2250 lb.

What angle of slope could the outfit negotiate and still deliver 1000-lb. pull? About 8½ deg.

Fig. 7 answers questions such as

With a 15-drawbar-hp. and an 8000-lb. outfit, it is desired to utilize 2000 lb. in draft. What are the various relations between speed and climbing angle? On level ground 2.8 miles, while with increasing slope angles travel speed must be decreased noticeably up to the point where the outfit negotiates itself only at 27 deg. 15 min.

Fig. 8 visualizes the influence of operating on various constant slopes and the influence of increasing slopes on the available drawbar pull and operating speeds for the same horsepower. Follow through the 5-deg. plane and

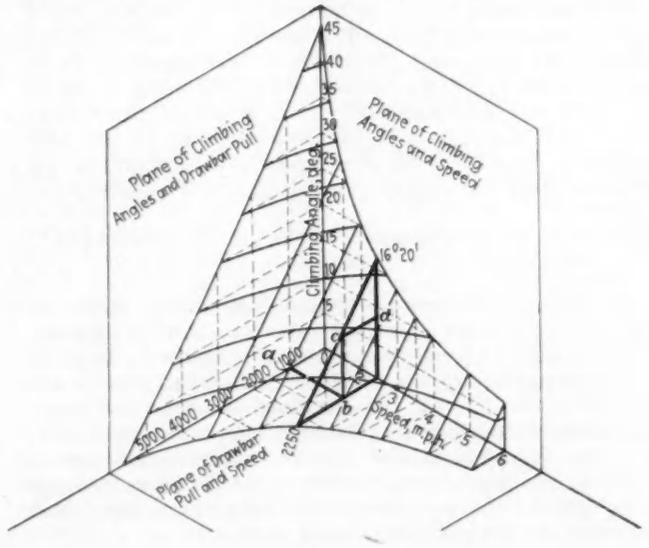

Plane of Climbing Angles and Drawbar Pull
Plane of Climbing Angles and Speed
Climbing Angle, deg.
Speed, m.p.h.
Plane of Drawbar Pull and Speed

FIG. 6

it will be noted that the available drawbar pull has dropped to a maximum of 4927 lb. at 1 m.p.h. and the greatest operating speed possible is reduced close to 6 m.p.h., while on a 15-deg. slope the same drawbar horsepower has a noticeably less flexibility since its drawbar pull at 1 m.p.h. is about 3500 lb. and the possible maximum speed is well above 2¾ m.p.h.

From Figs. 4, 5, 6 and 7 the designer's control factor is certainly the speed factor and the conclusion is posi-

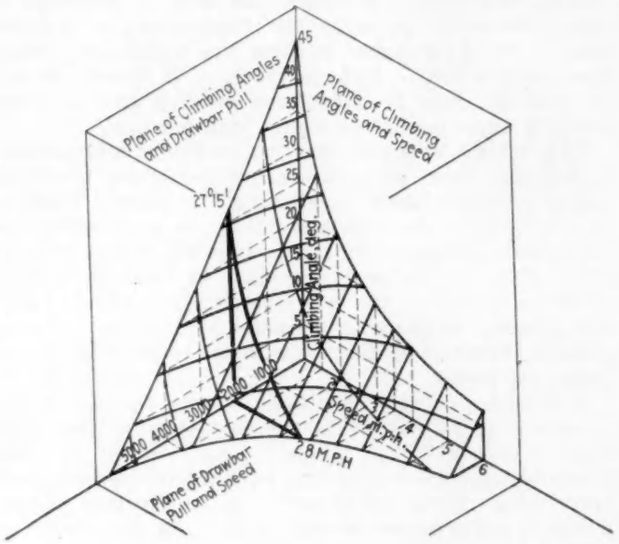

Plane of Climbing Angles and Drawbar Pull
Plane of Climbing Angles and Speed
Plane of Drawbar Pull and Speed
Climbing Angle, deg.
Speed, m.p.h.
2.8 M.P.H

FIG. 7

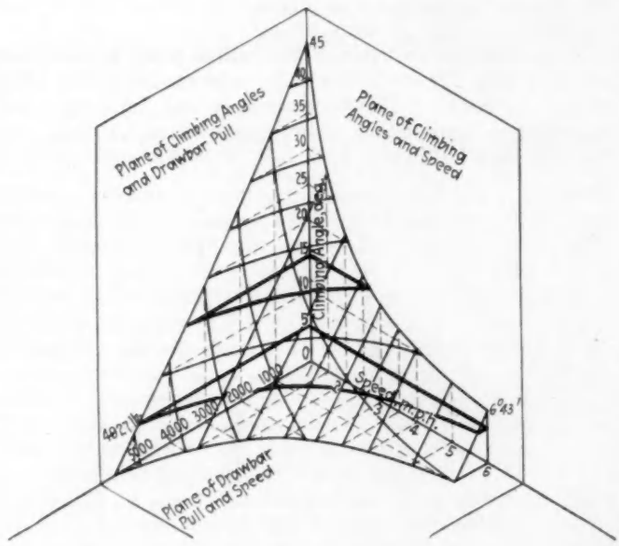

Plane of Climbing Angles and Drawbar Pull
Plane of Climbing Angles and Speed
Plane of Drawbar Pull and Speed
Climbing Angle, deg.
Speed, m.p.h.

FIG. 8

tive that the higher the speeds the less the tractor's flexibility as regards operation on rolling or level land, and available drawbar pull.

To visualize the relative values of acres plowed with respect to various soil resistances and with respect to different plowing speeds for a constant drawbar horsepower, Fig. 9 was constructed on the basis of the 150-lb. land. Equally good footing for all these conditions is assumed. The vertical scale records a series of varying soil resistance for a 14-in. bottom at a speed of 1 m.p.h. As the speed rises from 2 to 6 m.p.h. this soil resistance

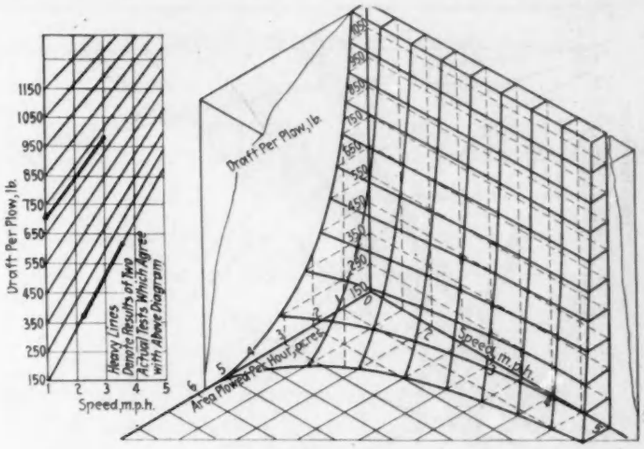

Draft Per Plow, lb.
Heavy Lines Denote Results of Two Actual Tests Which Agree with Above Diagram
Speed, m.p.h.
Draft Per Plow, lb.
Area Plowed Per Hour, acres
Speed, m.p.h.

FIG. 9

is taken to have increased according to the chart at the left, based on data reviewed in the previous article. Care is invited not to misunderstand the fact that the horizontal planes passing through any given resistance does not mean that this resistance is constant in that plane as the speed increases, but that the increment in resistance is incorporated in the diagram and at 6 m.p.h. the resistance of 150-lb. land will be 1070 lb. This warped surface is again a surface representing a constant horsepower, any point of which represents, by its relation to the three planes, the comparative value of speed in miles per hour, soil resistance and acres plowed. Soil resistances greater than those on the chart, and practically operated against are noted in a later diagram. The value of this chart lies in its emphasizing the value of lower speeds or that the possible accomplishment in acreage for a given theoretical expenditure of energy is in favor of low speeds rather than high.

The effect of rolling resistance on tractor accomplishment has not been thoroughly studied with respect to

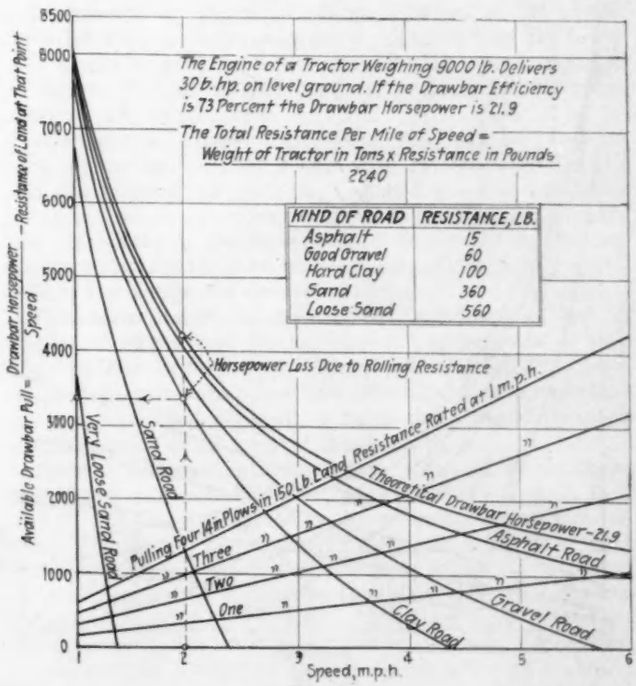

The Engine of a Tractor Weighing 9000 lb. Delivers 30 b.hp. on level ground. If the Drawbar Efficiency is 73 Percent the Drawbar Horsepower is 21.9
The Total Resistance Per Mile of Speed = Weight of Tractor in Tons x Resistance in Pounds / 2240
KIND OF ROAD | RESISTANCE, LB.
Asphalt 15
Good Gravel 60
Hard Clay 100
Sand 360
Loose Sand 560
Horsepower Loss Due to Rolling Resistance
Very Loose Sand Road
Sand Road
Pulling Four 14in Plows in 150 Lb. Land
Resistance Rated at 1 m.p.h.
Theoretical Drawbar Horsepower - 21.9
Asphalt Road
Gravel Road
Clay Road
Speed, m.p.h.

FIG. 10

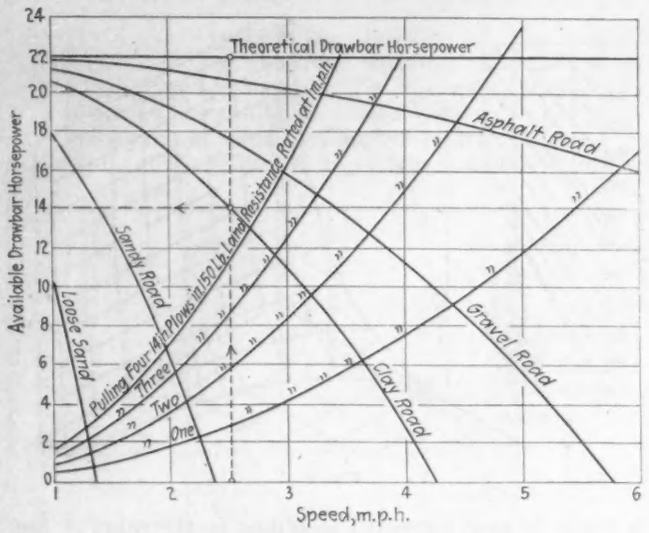


FIG. 11

loose soils. To go back over energy expenditure we find the following general summation:

> The horsepower delivered to engine shaft equals the horsepower of frictional transmission plus the theoretical drawbar horsepower. The last equals the available drawbar horsepower plus or minus the horsepower loss or gain due to the slope plus the horsepower due to rolling resistance. For any period of operation the horsepower due to rolling resistance equals the horsepower due to pure rolling at various speeds of tractor and plow plus the horsepower due to lug action, plus or minus the power losses due to inertia caused by speed changes and plus impact losses

As little guiding practical data are available and also inasmuch as authorities at this writing still are not in agreement as to theoretical analysis it will be assumed that the discussion which now follows is purely indicative and not to be considered quantitively authoritative when applied to tractors. Large numbers of experiments have been made covering rolling resistance on roads with a horse and wagon, types of equipment at slight speed variations, with railroad trains, suburban electric cars and trains and also with automobiles.

For our purpose we may use the latter rolling resistance data as coming nearer to our problem than the others, especially inasmuch as the data is supported by the experiments made by the Department of Agriculture in its experiments on steel tire widths and resistance on dirt roads. Data in the *S. A. E. Handbook*[2] will be used to start the argument pending the establishment of experimental constants with tractors.

Fig. 10 has developed upon it a curve of the theoretical horsepower from which are made deductions that indicate the losses due to overcoming the various kinds of soil roughness and compressibility, or such other soil deformation common in the process of tractor translation. The resistance is assumed to increase directly with the speed and the values as furnished in the tables are assumed to apply to a tractor at 1 m.p.h. The increase is taken to be directly with the speed over our low range of speeds.

For most practical conditions tractor footing during plowing seasons will lie in the field between the "Clay Road" curve and the "Asphalt Road" curve; in other words between the points where the tractor leaves a moderate wheel depression of say 1 in. on dry land to that where the depression is very slight. In dry, sandy or very wet soil we would meet worse footing up to the point where the depresison or slippage is excessive and the ability to maneuver is impossible even without serving power to the plows.

This diagram is crossed by radial lines rising from left to right. These indicate by intersections with other curves in land of 150-lb. resistance the limiting speed at which a number of plows may be negotiated with the available drawbar pull and with various qualities

[2]See vol. 1, pp. 22a, 22b and 22c.

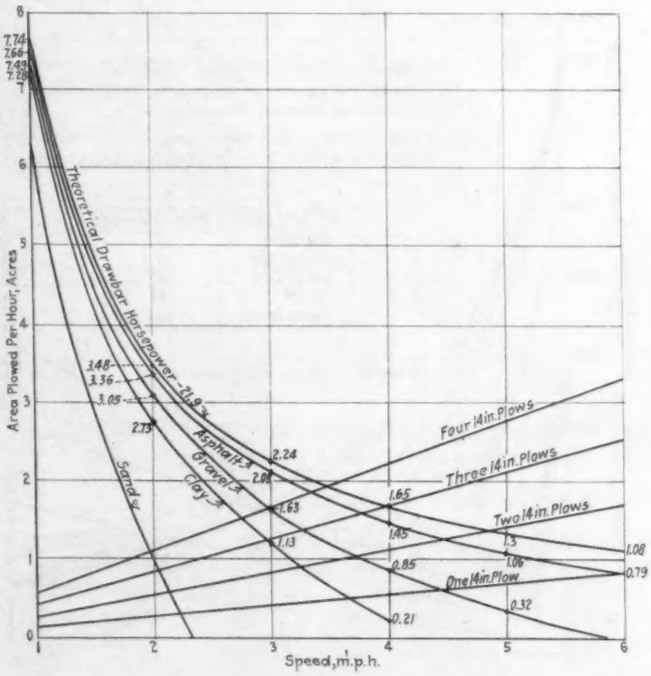


FIG. 12

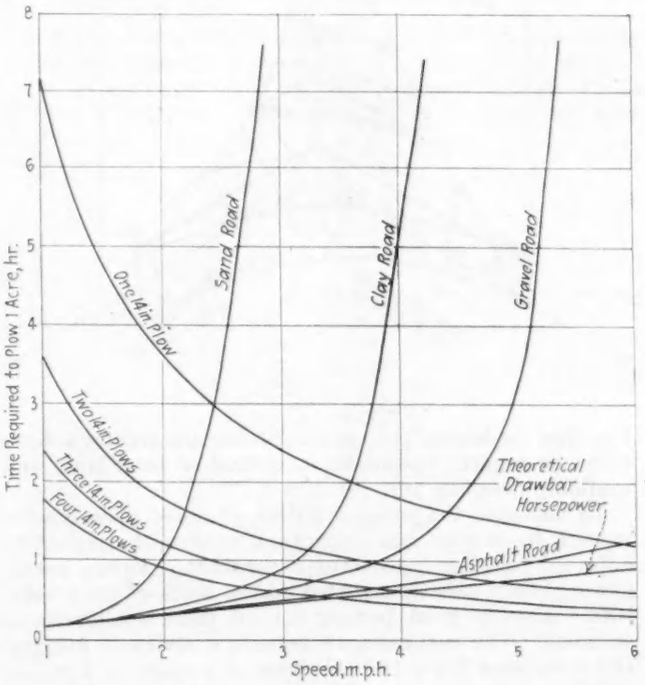


FIG. 13

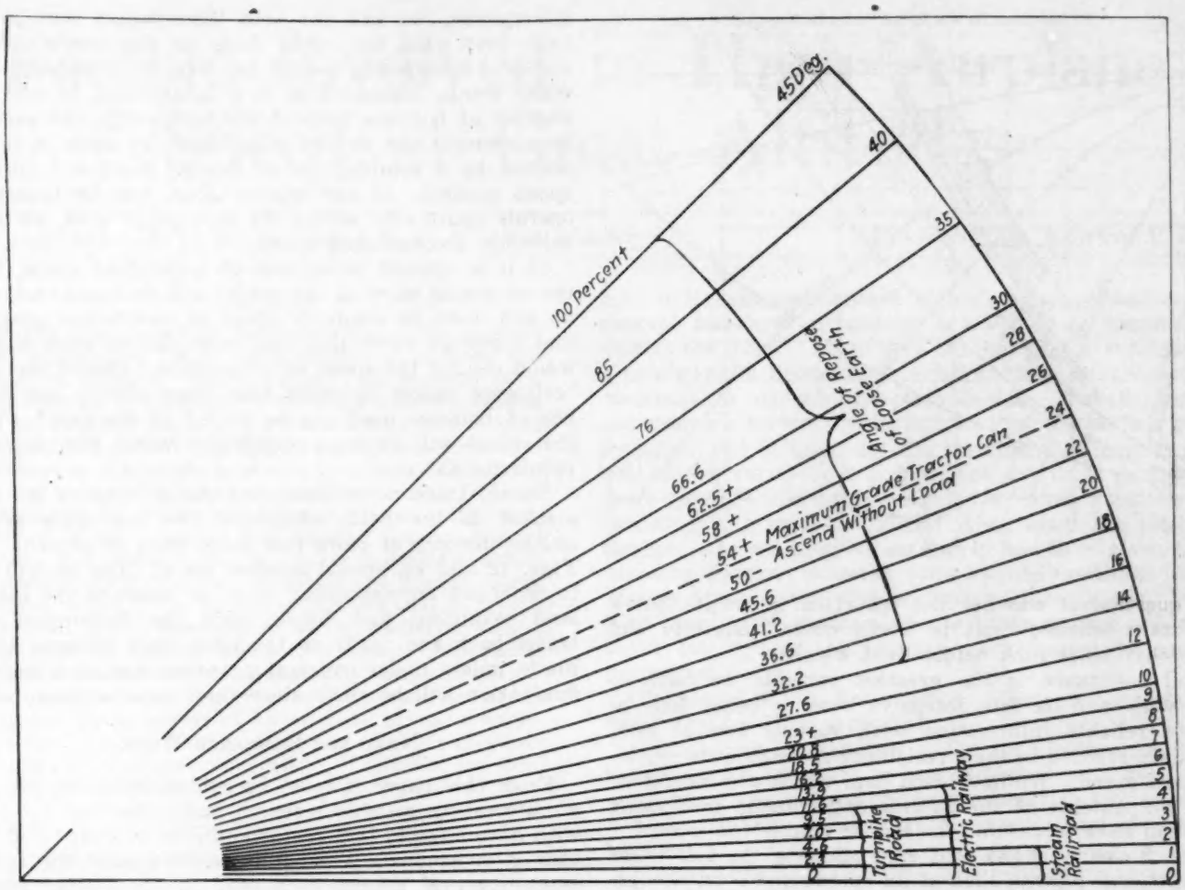


FIG. 14

of footing. The advantage of giving great attention to reducing the rolling resistance on loose or moist soils by every practical means is obvious from this diagram. The questions of weight, speed, pressure per square inch and proper lug and rim equipment deserve the closest attention.

Fig. 11 permits us to see the energy losses due to rolling resistance and their relation to speed and horsepower for various classes of soil, assuming one constant resistance to the plow of 150 lb. at 1 m.p.h. If another class of soil resistance is encountered, for example, on any farm in fixed areas which have different typical soils, which are to be operated upon, this diagram can be extended to cover it. (See Fig. 15.)

Fig. 12 is constructed from the data given in Figs. 10 and 11, to record the acreage accomplished when regard is given to rolling resistance. It is interesting to note that while the resistance of the soil to the plow is noticeably less in loose land, the surface conditions cause the rolling resistance to be greater, as a general proposition, and the two factors to a certain extent compensate one another. The designer, however, has a larger control over the reductions possible in rolling resistance than he has over any reduction in the soil resistance.

In these diagrams all calculations are made on the basis that the full possible plow width is cut, whether 12, 14 or 16-in. plows are used or others, so that the theoretical number of plows is the greatest width possible to make use of, i.e., two 16-in. plows would be impracticable, but correct theoretically. In practical operation we know it to be inadvisable to operate at a speed much lower than 1¾ m.p.h., though 25 out of 180 of the recorded makes of tractors have speeds which lie below this figure and 20 more operate at that speed, making 45 out of 180, or 25 per cent, with facilities for operating at 1¾ m.p.h.

The relation between the time required to plow an acre under the variable footings is reviewed in Fig. 13 and the influence of poor footing and speed is markedly evident. All power losses such as lug action and impact are considered to be incorporated under the rolling resistance and assumed to increase directly with the speed within the range we are considering.

For convenience in noting the relations of actual angles of slopes and the corresponding per cent slopes, Fig. 14 has been drawn. It would be valuable if we could ascertain what are the practical slopes operated against, and what per cent of farm areas would be made available with tractors over horse plowing.

Field slopes rise in certain localities well above those negotiated as roads. Fig. 2, as well as Figs. 4, 5, 6, 7 and 8, will be understood to have been carried out beyond practically negotiable angles. It is certain that probably 80 per cent of the land area which is cultivated by tractors would be in practically level fields, and the slopes negotiated by tractors will seldom exceed 15 deg., the maximum by far lying below 10 deg. However, slopes as high as 29 deg. have been ascended by tractors. For this reason it is worth while to consider carefully

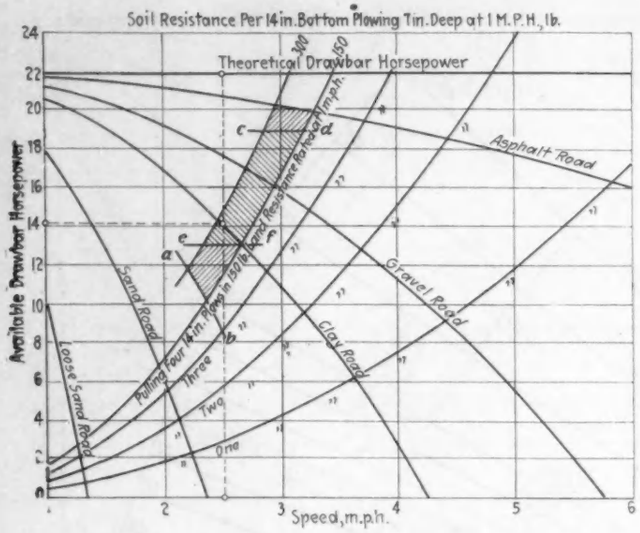


FIG. 15

the question of whether the reduction in weight below a certain sensible limit is worth while. Rigidity and durability must rank before light weight.

Soil resistance is the greatest variable we have to deal with, and on this, intensive work is being done to secure reliable information with various typical soils and data relative to their resistance in relation to moisture and speed. We have used data which are indicative only but outside of the specific experiments mentioned we shall have to assume the law or rule is the same.

Fig. 9 clearly shows that even allowing the full value in fractional plows pulled at all speeds and even though discount be made for the rolling resistance in the lighter lands so long as a footing is permitted, the advantage lies with moderate and low speeds of plowing.

There are doubtless some who might be inclined to the belief that this analysis does not have much practical value. To these and the groups of engineers and designers I would request special attention to an extension of this argument to Figs. 10, 11, 12 and 13. This, for brevity, will be argued relative to Fig. 11, and exhibited as Fig. 15.

Fig. 11 shows that in 150-lb. land the curve of four 14-in. plows requires horsepowers according to the value given by this curve. Should the land operated upon by a given 15-30-hp. outfit with four bottoms have *varying resistance* between ranges of 150 and 300 lb. per plow, we would have two curves between which the four plows would operate as shown on Fig. 15. Should the *footing vary* over this area due to land moisture conditions or nature of top soil between the very best noted as asphalt and some others, as, for example, clay or worse than clay footing *a b*, we find a diagram bounded by the four lines within which area are points of actual accomplishment on this field. The operation of the tractor, then, would be represented at any instant by a point floating about within this area.

Now, if we cross this area by a land *c d e f* covering the economical horsepower range of the engine drawbar horsepower, we can see both theoretically and practically just what the outfit, from an engineer's and designer's standpoint, should be able to accomplish. In other words, inasmuch as it is impractical to vary the number of bottoms without much difficulty, the variable requirements can be met if provision be made in engine control by a combination of change gears and throttle speed control. If the engine, thus, can be caused to operate constantly within its economical area, we have certainly accomplished much.

If it is desired to operate at a constant speed, then the operating point of the engine will fluctuate vertically up and down at whatever speed is maintained constant and sideways from this line only, due to such slip as would change the speed of translation. Should the land resistance values be other than those chosen the number of bottoms used can be varied to the point where the values will lie most completely within the range of requirements.

Should tractors in field contests be attuned by this method to the field conditions, the field data would quickly become of more real value than at present. In Figs. 12 and 13, should another set of lines be laid out to represent corresponding acres or hours to the 150-lb. land conditions and 300-lb. land, the fluctuation will travel back and forth on the plow lines between these limits unless under constant governor control when the fluctuation will be small since they cover slippage only.

NEED FOR RESEARCH WORK

From this paper it must be evident that the amount of interesting reliable research work that can be done with advantage to the tractor and plow industry and the user is enormous. When it is realized what the actual expenditure of energy each year on the United States farms really is and that the majority of it can be done by mechanical power; that a very large part of it can be performed by a properly designed tractor and that estimates of this energy expenditure show it in actual horsepower to be greater in quantity than all other energy expenditures of industry in the United States including mines, manufacturing, lighting, etc., we must admit that every available resource of engineering skill and scientific research must be expended and quickly, to raise the tractor and implement industry to one where the most exact and careful design will be evident from every possible economic standpoint.

Basic data must be established along many lines; special test equipment and apparatus must be designed and built; whole series of experiments must be carried out at various seasons and in different soils; these latter must be studied in various conditions of moisture content; plow and engine design features must be shifted and standards adopted toward which the whole industry will then be enabled to work for early sensible economic solutions in the general interest of the Nation as a whole.

Acknowledgment is made to D. L. Arnold and T. G. Sewall for valuable suggestions and help on diagrams and calculations and to V. R. Whelan for reproducing the diagrams here given, all of the experimental department of the International Harvester Co.

Factors Involved in High Airplane Speed at Great Altitudes

By COMMANDER H. C. RICHARDSON,[1] U. S. N. (*Non-Member*) PENNSYLVANIA SECTION PAPER

ABSTRACT

THE development of the supercharger for aircraft engines has led to the possibility of hitherto unheard-of speed of transportation. An analysis of a definite case is presented to show the different aspects of the problem in a practical form, with a view toward determining what can reasonably be expected. An attempt is also made to arrive at a knowledge of the elements involved whose improvement will effect the greatest gain. The supercharger overcomes the deficiency of the ordinary gas engine's serious loss of power at great altitudes, due to its inability to obtain sufficient oxygen for the combustion of a normal charge of gas which, in an engine of conventional design, is essential to the development of its maximum output. The required and available horsepowers of the airplane itself are considered mathematically, airplane propellers and their characteristics are discussed, the climbing and flying speeds of an airplane having a supercharged engine are presented and the miscellaneous factors involved are enumerated. [Printed in the April issue of THE JOURNAL]

THE DISCUSSION

MR. STERNBERG:—When Major Schroeder was up about 36,000 ft. he lost consciousness and fell. Are there any data on how many seconds away from the earth he was when he regained consciousness?

COMMANDER H. C. RICHARDSON:—He fell about 5 miles at the rate of 300 m.p.h., and he became conscious at an altitude of about 300 ft., I believe, so he must have been only a few seconds distant from the earth. He managed to pry his eyes open and saw that the altimeter showed 300 ft. It was of the repeating type. At that time he thought he was up 2300 ft. But he was able to recognize his position and put on power. He climbed to about 2800 ft. Then he concluded he might become unconscious again, and so he steered for clear country. In his climb for 2800 ft. he was able to get away from a field on which he did not wish to land. He wished to reach McCook field, but when he attained 2800 ft. he found his eyes were shut. He pried them open again and was able to reach McCook field and make a landing before he finally collapsed.

To give an idea of what might be endured by those who wish to go to great altitudes, I understand that his heart expanded 9 in. and that his ribs were pushed out by his heart. Just what other physical effects he had I am not sure. I know that when I saw Major Schroeder recently he was recovering fairly rapidly. He had to wear goggles but could see and appeared to be fairly normal, except that he did not dare to subject himself to any unusual excitement.

G. A. RICHARDSON:—The use of a variable-pitch propeller was mentioned. Is there any inherent weakness in the use of the propeller under the conditions that would have to be met as compared with gearing? What is the general design of propellers in which it is possible to change the pitch? Have they any mechanical weakness?

COMMANDER RICHARDSON:—No, there is no mechanical weakness in the variable-pitch design. The design is not clean all the way to the hub, as it would be in a good propeller, and to introduce the variable-pitch devices and control the variable-pitch while the engine is in motion there must be additional weight over what would be required in a normal propeller. Also, when the pitch is changed, the efficiency is somewhat less than given by a properly-designed propeller for a specific condition. But, as was shown in the efficiency curves, the efficiency holds high and fairly uniform as the pitch is changed, provided the velocity of advance is increased in proper proportion.

CHAIRMAN A. K. BRUMBAUGH:—Has anyone actually constructed such a gear set?

COMMANDER RICHARDSON:—Not for airplane use. The variable-pitch propeller is now designed so that it will work negatively and bring the airplane to a stop quickly.

J. A. ANGLADA:—What are the possibilities of helicopters?

COMMANDER RICHARDSON:—The helicopter can be built and can probably carry a crew. It can be divided into several units, so that the torque will not cause difficulties, and it will lift straight along the propeller axis. That will not necessarily be vertical. If I were less sure of that, I would have more faith in the helicopter. All that it will do is to pull on the center of gravity along the line of the propeller axis. If the problem of stability can be solved, and probably it can be by the introduction of control surfaces in the propeller blast, so that the machine will not roll over like an umbrella when the wind hits it, the helicopter may be possible. I understand that designs have been worked out both in this country and in France, and each of the two designs probably has considerable merit. They amount to building the helicopter propeller so large that it is practically a pair of airplanes running around a vertical shaft.

The other difficulty with a helicopter is in regard to what will happen when the power fails. Most inventors advise carrying one or two extra powerplants. It may be possible to make the helicopter blades of such a section that they can be reversed, so that when the machine starts to fall the same result can practically be brought about that obtains with an airplane when it goes into gliding, and that the helicopter's own potential can be used to produce the propelling force. That will require putting a brake on the propeller-shaft. If the gliding condition can be produced with those blades, we will get closer to a solution with the helicopter; it does not appear impossible. The lifting power is certainly available, but unless an approach is made to what really amounts to a tentative airplane, one of the principal advantages that the airplane has will be lost. With a helicopter, to lift 1 lb. a 1-lb. thrust must be developed. With a good air-

[1]Chief engineer, Naval Aircraft Factory, League Island Navy Yard, Philadelphia, Pa.

plane, only 0.1-lb. thrust is required to lift 1 lb. The airplane itself converts the propeller thrust into a much greater lift. When the helicopter meets these conditions it will begin to enter a possible field. The main difficulties are its instability and what will happen when it must descend without power.

G. C. LOENING:—Is there anything in the variation of the diameter of the propeller that might aid in overcoming the difficulties? Would it be possible to carry along two propellers and vary their diameter by shifting gears, for example?

COMMANDER RICHARDSON:—That should be a very interesting development. If the diameter should be increased, the same pitch might be retained and still hold the engine down. The propeller would again be acting as the governor, which is the function which it must perform when great altitudes are attained and the engine power is maintained. Sperry uses a device similar to that in the driving of his electric generators. He has blades which have springs in them to modify the propeller action, acting as a windmill instead of a propeller. The springs in the blades merely vary the pitch and not the diameter of the propeller, so that he practically has a constant-speed generator and can control the voltage of the generator at different speeds of the airplane. It is not a variable-diameter propeller. I have never heard of a variable-diameter propeller, but it appears to be a possibility.

MR. COOK:—Does not a propeller with a heavy pitch have a tendency to churn the air instead of pushing it backward?

COMMANDER RICHARDSON:—It does if the machine is not proceeding at the proper speed. That is, if the pitch is too high for the speed of advance. The pitch of the blade of the propeller ought to be suited to the speed of advance. Most of the propellers work well at a speed of advance in which the pitch speed is about 25 per cent greater than the speed of advance. With a high-pitch propeller working under those conditions, I think there will be no more churning than with another propeller working at probably higher revolutions and lower pitch. The churning comes about when the proper speed of advance relative to the pitch is not secured. I refer to geometrical pitch. The pitch of a propeller is a variable quantity which no one can really measure.

C. D. LEFEVRE:—What is the cause of the high velocity of the wind at great altitudes, from west to east?

COMMANDER RICHARDSON:—I do not know.

MR. LEFEVRE:—Would the revolution of the earth ever have any effect on the wind velocity? If so, would it not cause a wind from the east rather than from the west?

COMMANDER RICHARDSON:—It would seem so, following the analogy of the trade wind. It may be a counter-trade wind. The regular trade winds come from the northeast. They are blowing to the west; at their terminus they become heated and start back, and it may be that it is a counter-trade-wind effect; but if that were the case we would expect to have a southerly component wind. I understand that at Dayton the wind has been found coming from slightly north of west, which seems to disprove that idea. I understand that observations have been made at the equator, as far north as 45 deg. of latitude and still farther; and that, in general, at an altitude of about 30,000 ft. the wind is still westerly, even though at the equator or up to a latitude of 45 deg. That makes the condition interesting and difficult to account for, and I have not heard of any real explanation. But as the facts given us by people who have been there are in general accord, we must believe and find the reason.

LIEUT. RALPH S. BARNABY:—Are there any accurate data on the horsepower absorbed in pushing an airplane equipped with a supercharger through the air?

COMMANDER RICHARDSON:—I have seen no such data. The supercharger gives a somewhat bulkier nose to the machine. The horsepower that is absorbed by the supercharger itself apparently does not affect the horsepower available from the engine, probably because the amount of supercharging is not controlled automatically, but by hand. The supercharger is used to any degree that is desired.

LIEUT. BARNABY:—From photographs of the installations that have been made, it appears that the head resistance is increased greatly by the addition of the supercharger.

COMMANDER RICHARDSON:—That is very likely true. All such things must be considered. When a supercharger and a propeller are installed we do not get something for nothing, the machine must carry that weight instead of gasoline and, while we may expect to increase the radius of action, the way to get that is to revise the design of the airplane rather than to change the design of the engine. There is no need to go to great altitude to obtain the radius of action. If we wish to arrive quickly there is an advantage, but with the least amount of gasoline there is no advantage in going up. Besides, in going up the gasoline is lifted to a great altitude and its weight is reduced so that it is not available to return its value when coming into the glide.

LIEUT. BARNABY:—If the weight of the supercharger were put into the engine, could not sufficient additional power be obtained so that all the power needed for the altitude would be obtained? For instance, the Curtiss triplane manages to climb high without any supercharger because it is a much cleaner design and the engine probably develops somewhat more power. It appears that by putting the weight of that supercharger into the engine it would be found that the design had a somewhat higher power on the ground and that the same effect would be obtained at great altitude.

COMMANDER RICHARDSON:—The principal reason some excellent results were obtained without a supercharger in that case is that the plane was very much over-propellered at ground level, so that at great altitudes the propeller did not permit the engine to race, but did permit it to develop all the power possible without running at an abnormal number of revolutions per minute.

LIEUT. BARNABY:—By installing a variable-pitch propeller without the supercharger on the same airplane, they could get the desired climb near the ground, by reducing the pitch, and could then adjust the propeller so that they could increase the speed as they went up.

COMMANDER RICHARDSON:—In his great-altitude test Major Schroeder was not attempting to attain the maximum speed obtainable but altitude. He was therefore working at a point on the horsepower curve where he had reserve horsepower and he did not meet the limit until he reached the maximum of his altitude. If he had attempted to go at higher speeds up there, he might not have done so well. The supercharger certainly would have had probably two or three times the brake horsepower available that he had, because he did not have the density of charge, and he could not get the horsepower.

LIEUT. BARNABY:—He had no way to absorb that extra power except by speeding up?

COMMANDER RICHARDSON:—That was the only way. Under those conditions, I believe that the horsepower reaches about the 1.1 power of the density ratio.

The Diesel Engine of the German Submarine U-117

By COMMANDER HOLBROOK C. GIBSON, U. S. N.[1] *(Non-Member)*

MOTOR-BOAT MEETING ADDRESS *Illustrated with* PHOTOGRAPH

SHORTLY after the armistice, I had the good fortune of witnessing the surrender of the German submarine fleet. The most noticeable thing was that the submarines came in maneuvering on their engines. They did not do it theoretically; they did it practically. Following that I was sent on a mission to inspect submarines. I inspected about forty of the 170 German submarines that were at first surrendered. I then went to Germany and inspected the remainder of the German submarine fleet, about 185 vessels; some of them were new and others were in various stages of completion and repair.

We found that practically all of the engines were of the Machinenfabrik Ausburg-Nürnburg four-cycle Diesel type. In the submarine service during and prior to the war, we had always believed that the two-cycle engine was the only type worth while. The Germans evidently did not share this opinion. We found that there were but five Krupp two-cycle engines, and that all were out of repair. Practically the entire German submarine fleet was equipped with the Machinenfabrik Ausburg-Nürnburg four-cycle Diesel engine, divided into four very distinct classes of 300, 550, 1200 and 1750 hp.

While riding in one of the former German admiral's barges, I noticed that we were going very fast, then that we stopped, backed and went ahead very quickly, much more quickly than in any motor boat I had ever been in before. I found the barge was equipped with a beautiful 100-hp. air-starting Diesel engine. Later, at Hamburg, we found two engines of the 3000-hp. type, with ten cylinders. But they are all of the Machinenfabrik Ausburg-Nürnburg type, and they all have the same fundamental principles; the only difference being that they make certain mechanical changes in the design as the engines increase in horsepower. The 100-hp. and the 300-hp. six-cylinder engines run at 550 r.p.m.; the 550-hp. and the 1200-hp. run at 450 r.p.m. When they jump up to the 1750-hp. engine they cut down the speed to 390 r.p.m. It is a very noticeable fact that they are all six-cylinder engines, with air compressor and spray air injection, except the 3000-hp. engines, which have ten cylinders. They ignore the eight-cylinder unit. There is a reason for jumping from six to ten cylinders. We have a number of eight-cylinder engines on our submarines, and they are giving trouble in some cases.

THE ENGINES OF THE U-117

We brought back several of the submarines, but not until after all the Allied countries had taken what they wanted, and our boats had been abandoned for six months. The engine hatches had been left open, and the engines were not even drained down. However, we crossed the Atlantic with them and nothing happened.

I have had the good fortune of dismantling the German submarine U-117 at the Philadelphia Navy Yard. We have taken out the engines, which are of the 1200-hp. type, a typical engine which was used more than any other type in the German submarine service. It has six cylinders, with an air compressor on the forward end.

To my mind the submarine Diesel engine is a special breed. It bears the same relation to the Diesel engine industry as the aviation engine bears to the gas-engine industry. It must be an engine with the greatest strength, of the lightest weight, and must stand the most severe treatment; most important of all, it must be reliable and accessible; it must be everything that it is difficult for an engine to be. The Germans have done things that we have not done. They have overcome certain difficulties that were bothering us. We were getting along fairly well, but they were getting along somewhat better. Any country which staked its all on a submarine campaign must have had some good ideas to start with. The Germans made some very beautiful castings; they are really remarkable; light, clean, and made of steel. Everyone who looks at the castings admires them.

The six-cylinder engine is made in three sections. Instead of being bolted on the flange, the bedplate comes right up and forms what might be termed the housing; the bedplate and housing are integral and thoroughly ribbed. The sides of the cylinders come down and are bolted to each other. The cylinder jackets come out in a skirt, and that skirt gives the vertical structure and strength. With this casting and cylinder jackets bolted together, a very rigid construction is obtained, but one that is very light, comparatively speaking; lighter than cast-iron construction. The engines have a one-piece crankshaft, with six throws, and two throws for an air-compressor on the forward end. The workmanship is excellent. We put calipers on the main bearings and on the crankpins, and we could find no difference down to 0.0001 in. The usual connecting-rod construction is used with an eye in the upper end for the wrist-pin. This engine runs at 450 r.p.m. and has a 16½-in. stroke, so the piston speed is very high.

We tested the cylinders with calipers and they are all round after running some 40,000 miles, which is very remarkable. The pistons have five piston-rings, and the pistons taper gradually from the top to the bottom working ring. The piston, which is 17¾ in. in diameter, is run with 0.010 and 0.014-in. clearance. The wrist-pin bearing runs at 0.004-in. clearance, which is also remarkable. The usual practice in this country is to put an ordinary shell or bushing in the eye of the connecting-rod. It is sometimes of babbitt and sometimes of bronze, and comparatively narrow; it does not extend out to any distance on the sides of the connecting-rod. The pressure is very high, and incidentally it is very warm in there. The Germans circumvented any difficulty in that place by putting in a steel shell or cap, which might be

[1] Submarine Repair Base, League Island Navy Yard, Philadelphia.

called a steel support; it is double the width of the connecting-rod. In other words, they took the extreme width of the piston inside, as much as they could, and made it a wrist-pin bearing. That wrist-pin bearing is babbitt and, for some reason which I do not know, the wrist-pin is hard. In other words, the construction is practically the same as in an ordinary crankshaft bearing with a hardened pin. It is absolutely smooth and round and straight. To show how these wrist-pin bearings can take care of the excessive pressures, when we dismantled this engine we found that two of the cylinders were badly scored. We traced this back to the fact that when this boat was surrendered the muffler stop valves had been left open and the rain water had rusted two cylinders. At the time we knew nothing about that, but started the engine and ran home on it. Also, one air-compressor cylinder was so badly scored that the lower end was streaked and cracked, but still it ran well. There was no excessive heat, and not a sign of wear on the wrist-pin bearings. In our own engines it is very difficult to ascertain what causes the trouble in case of a piston seizure; whether the wrist-pin or the piston grabs first and causes the wrist-pin to seize.

In this Diesel engine we found that one of our greatest troubles had been overcome in a simple way. The cylinder heads are round and flat, and about 1 ft. thick. They are plain ordinary castings, with inlet and exhaust valves diametrically opposite on the center line of the engine, an air starting valve, a relief valve and a two-spray valve. The two-spray valve construction is carried out in all their engines, from the 550-hp. size up. I have been asked the reason for the two-spray valves. There are several good reasons. They have the exhaust valve and the inlet valve as large as possible. There are two round holes in the head and a round cylinder. If those holes are brought together there is no place for a spray valve, and if the valve holes are made small enough to get a spray valve in between, the whole head is weakened. So, when they needed great power, they used the two-spray valves. The two-spray valve construction works very well and a very good atomization of fuel is obtained.

It has been asked how they manage to make both spray valves lift at the same time; that is, so that one does not lift without the other, and so cause irregular firing. This is simple when explained but consists of several steps. What they have is a cross; it might be called a crosshead guide, which goes up in the middle to lift the two valve-stems. Where the crosshead guide takes on the valve-stem, they have a self-aligning bearing or dished washers. When the valve is being set, one valve is lined up first and then the other valve is lined up to it. Inside of the valves there is a distance washer which is accurate to 0.0001 in. so as to get the exact lift on each valve. There is no trouble if the valves are properly lined up; they work exactly like one valve, and can hardly be considered in any other way.

The engine is air starting and reversing, but it is reversed by raising the valve gear off the head, clear of the camshaft; the next part of the operation is the translation of the camshaft and the last part the lowering of the valve gear to normal position so that the cam rollers fall on another set of cams. That is ordinary construction. There is nothing very remarkable about it, except that it is carried out very well. The reverse can be actuated in 4 or 5 sec., or just as fast as the wheel can be worked.

The cylinders are connected in series, with two levers, and when both levers are pulled back the air is admitted to all six cylinders. They are connected up straight through the heads. When the engine attains sufficient speed, as after several revolutions, one lever is shoved over to the running position; when three cylinders pick up the firing, the other lever is shoved over to the running position. The engine starts from being entirely cold, with no trouble.

The engine is remarkable in its maneuvering qualities. We put one on a test stand to make certain tests required by the Bureau of Steam Engineering for minimum horsepower. The minimum horsepower of this engine is just sufficient to turn it over; that is, to overcome the engine friction. It will run with perfect combustion, delivering no load at the flywheel. By perfect combustion I mean that the temperature is not excessive, and the exhaust is absolutely invisible.

Workmanship

The workmanship on the engine shows exacting care throughout. It is a wonderful example of thoroughness. Every thousandth of an inch is accounted for. Everything about the engine shows that it is put together scientifically, and for a reason. And, above all, it is put together well. One of the foremost engineers in this country on Diesel engines looked over this engine and admitted that there were several very fine things about it, but said that such workmanship is very expensive; and so it is. For instance, the piston is an ordinary cast-iron piston except for the workmanship on it. Every ring fits exactly. The top working ring has 0.008-in. clearance and the next ones 0.006, 0.003 and 0.002-in. clearance respectively. The working rings are all lap-jointed. Each ring is secured by a dowel pin. The bottom working ring is an oil-wiper, and at the bottom of the piston also there is an oil-wiper. That oil-wiper looks the same as the other rings, except that the upper part of the ring is beveled off; the lower part is like an ordinary working ring. The confidential instructions we managed to obtain show that when this wiper-ring wears to one-half the width of the ring, it should be renewed.

The lubrication of this piston has been a source of many questions and many arguments among persons interested in lubrication. The only lubrication that the piston gets is from the splash, and there are the two very efficient wiper-rings to take off any oil that gets up there. In addition, there is an auxiliary lubrication system which is taken from the main-bearing supply. This consists of a manually-operated spring-valve, one for each working cylinder. By pressing down on these little valves, one for each working cylinder, oil is squirted into the cylinder. We figured out that this oil makes contact at about 3 or 4 in. above the bottom wiper-ring when the piston is on the bottom stroke; on the top stroke it shoots right into the crankcase. The instructions read to squirt oil on the piston about every ½ hr.; that is all the lubrication that the piston gets and that is why it does not carbonize.

It is all a question of workmanship. With a round piston and a round cylinder, the friction is eliminated to a very large extent. To illustrate this, one man with a 2-ft. bar can jack the engine over with one hand. Everything is exact.

In some of our large engines in this country, getting oil up into the wrist-pin is one of the great problems. The connecting-rod is naturally hollowed out to reduce the inertia forces and to make it lighter. When that big rod becomes filled with oil, the inertia forces acting on the oil have a tendency to take the oil away from the

wrist-pin. To overcome this tendency, some of our engines have what we call a foot-valve or check-valve, in the foot of the rod; this is very hard to remove in case it sticks or chokes, particularly at sea. The Germans have hollowed out the connecting-rod and simply put an ordinary plug into the bottom of the connecting-rod and run a pipe up to the wrist-pin, instead of forcing the whole connecting-rod full of oil and letting it ooze out to the wrist-pin.

The pistons are oil-cooled. The lubricating oil and piston-cooling oil all return to a sump tank and are pumped from the sump tank through a cooler; from the bottom of the cooler the oil goes to the main bearings. Another pipe comes from the top of the cooler, and this leads to the piston cooling system.

The pressure delivered to the cooler is about 60 lb. per sq. in., but by the time it gets through the cooler and to the bearings it is reduced to about 30 to 40 lb. per sq. in.

There is an automatic regulator on the forward end of the engine so that just the right pressure and quantity are delivered to the main bearings; all the remainder goes to the piston-cooling system. Thermometers are provided so that it can be seen that the piston-cooling circulation is not restricted, which is very important for marine use. At sea it is necessary to know if there is salt water in the lubricating oil, because this causes trouble with the piston-cooling system.

Air Compression

The 550-hp. and larger engines all have the four-stage air-compressors; that is, on this engine there are two cylinders of the first stage, two of the second, one of the third and one of the fourth; the pistons are exactly the same, except that one has a third stage and the other a fourth. That, also, is run very close. They take great care that each stage is fitted with a separator and a cooler. It is the practice to blow down every 15 min. to remove any water or oil in the air. The engine exhausts into what is called a dry muffler. No water is put into the muffler to make it silent, or to keep it cool. The muffler is of course water-jacketed.

The Germans were obviously short of material and did things on the engine which I suppose were done through necessity. They have done things with steel piping which we do not yet know how to do. All their piping is of steel, with the exception of a few gage lines. Even the spray air lines are of very small pipe made of steel. All over the engine there are very fine examples of the welding of steel plates and pipes. The entire exhaust header, which is water-jacketed, is made of very thin plate welded. It weighs about 1200 lb. for this size of engine, which is very light.

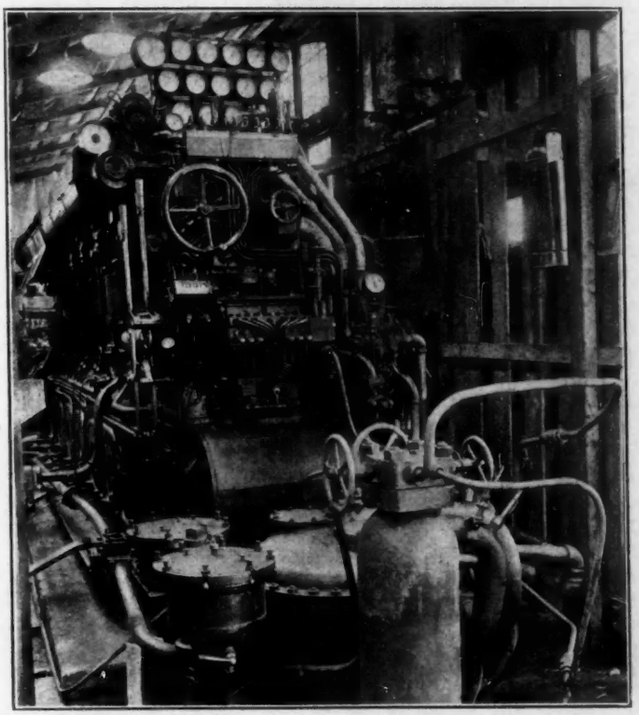
The engine has also a very unique device on its forward end, called a spray air regulator. The spray air is regulated automatically for the horsepower or load that is being developed; the more horsepower the engine develops the higher the spray air. The Germans use their engine air compressors for pumping up the ship's tanks; they can pump up to 3000 lb. When we looked at the engine, we agreed that we did not like the arrangement of the compressor. The air-compressor valves in some of the stages are not very accessible.

Summary

The Diesel engine is not a cheap product and cannot be made cheaply. Perhaps it can be made cheaply and sold; but it cannot be made cheaply and run with any great success or reliability. It all depends on what they are being used for. A high-grade engine must be well made, and the material in it must be as near perfect as possible. The engineer and the metallurgist must cooperate in this.

The Germans are not yet satisfied with their engine. We had evidence all through the German submarines that they are still experimenting. We find slight differences in the mechanical details. They are trying all the time to perfect what they already have, which is very reliable, comparatively speaking.

Regarding our own engines, we have something yet to learn. But to build a Diesel engine costs money. The



The Engine of the U-117 as It Appeared After Being Removed from the Submarine and Set Up for Testing

German Diesel-engine builders were backed by the German Empire. They have a good design; we are now trying to take the good points from it and adapt them to our own use. We do not say that what we have is all wrong, because it is not. We may approach the problem in an entirely different way, but it is well to take the good points they have and by adding those we have we ought to go them one better. That is what we are trying to do.

We are in difficulties in this country on account of patents. We have several companies building Diesel engines and competing with one another. It is all right when building automobiles to do private research work and guard the secrets very carefully, but the submarine Diesel engine is one for which there is no demand in the commercial market.

The logical way of going into the problem of developing a real submarine Diesel engine is either for the Government to do it or back the Diesel engineers of the country in research work, with that primary object in view. I am confident that the Diesel engine is past the experimental stage. I have seen Diesel engines of 100 to 1750

hp. in operation. The Diesel engine is a practical proposition.

The Discussion

CHAIRMAN JOSEPH VAN BLERCK:—Is my understanding correct that the oiling system is a pressure system on the main bearings?

COMMANDER H. C. GIBSON:—Yes; the pressure is about two atmospheres.

CHAIRMAN VAN BLERCK:—Is their reason for having the babbitt in the wrist-pin to cut down the friction, reduce the heat and keep the wrist-pin from wearing flat?

COMMANDER GIBSON:—I can understand the babbitt, but I do not understand why the wrist-pin should be case hardened with a babbitt bushing.

CHAIRMAN VAN BLERCK:—The case-hardened bearing is always better, according to my experience. If we could have case-hardened crankshafts today we would accomplish something. With tractor and truck engines, where there is dust to contend with, the only serious difficulty is the wearing of the crankshaft. An engine which has been subjected to dust, when taken apart shows everything else perfect; the piston-rings and babbitt bearings have not become worn, but the crankshaft is worn flat. That is the first place to look for trouble when there has been any dust in the engine.

COMMANDER GIBSON:—The usual practice I have seen in wrist-pin bearings is to have a bronze bearing in the connecting-rod.

ERWIN CHASE:—Do the Germans consider that there is any future in the two-cycle Diesel engine for submarine use, or have they abandoned it entirely?

COMMANDER GIBSON:—Several German submarine officers have said that they have no use for them, because there is always danger of getting salt water into the piston-cooling oil which in a two-cycle engine is very serious on account of the heat. Because there is so much heat to dissipate, the coolers and pumps must be much larger than in a four-cycle engine. They favor the four-cycle type. In fact, many of the European countries are building four-cycle engines. For submarine use, I favor the four-cycle type.

H. C. GIBSON:—Diesel engines, like all other engines, are needed for the work they will do and, if a properly constructed Diesel engine will work without trouble, 10 to 20 per cent more spent in the initial cost of that engine is more than paid for in its economy of operation and decreased depreciation. It is most serious that we should at any time consider that we must subordinate accuracy of workmanship in commercial engines. The subordination of accuracy of workmanship to price alone is not the proper basis upon which to construct any piece of mechanism, especially a complicated, difficult piece of mechanism subject to such high stresses.

COMMANDER GIBSON:—I agree with that. With an engine that will run without any trouble and reach port not only once but several times, the confidence of the crew has been gained and they will swear by the engine. They will then understand that if little things happen they are merely incidental, and that such things will happen to almost any engine. Confidence in an engine is a thing to be cultivated. The commercial engine, as well as the marine engine, must be reliable. Reliability requires good workmanship and design. Good design and good workmanship go together.

A MEMBER:—I can say from experience that we need better workmanship. As an instance, on a ship with a new engine the engineer was suspicious of the engine because of the finish and the way the connecting-rod bearings were fitted. His suspicions were correct; the engine was out of line. That shows the need of good workmanship.

A. M. WOLF:—At our December meeting we had an interesting paper on the Torsional Vibration of Crankshafts, in regard to the Diesel engines employed on our submarines. In view of the difficulties we have had, what has been Commander Gibson's experience regarding the vibration encountered in the German Diesel engines? What speed did he find to be the critical one, and what was the extent of the vibration?

COMMANDER GIBSON:—I cannot state the figure offhand, but the engine is very sensitive in regard to critical speed. There is a certain spot at which the vibration is very noticeable, which is evident just the minute it occurs; but below or beyond it the engine is as steady as a rock. The minute the critical speed is reached the engine makes a tremendous racket. So, we give it more fuel or regulate the engine as the speed is increased or decreased.

CHAIRMAN VAN BLERCK:—In regard to the workmanship on the German engines, I think we would have no difficulty in getting even better workmanship if the Navy Department, for instance, built one good engine and then put a thousand of those engines through the shop all at once. That would guarantee better workmanship than the Germans ever had. I think it is not the right idea to build one engine today and six months from now another.

A MEMBER:—Has Commander Gibson any thought on the solid injection as compared with the air-injection system?

COMMANDER GIBSON:—All the German engineers continue to use the spray air. The Vickers people in England use the solid-injection system. I believe the solid-injection system will come, but it gives poorer maneuvering qualities to the engine at present, in comparison with spray air. The German engines, in addition to their spray air regulators which give certain definite spray air for certain speeds and loads, have a control on their spray valves which allows a spray valve to lift a certain definite distance, according to the amount of the fuel to be delivered to the engine; the more the fuel required, the greater the lift is. The problem is involved with the spray-valve control. It is very unique, and it works beautifully. The engine can be shut down to low power with very little fuel and very little lift of the valve and complete combustion is obtained. I think that could not be done at present in the solid-injection system.

G. F. CROUCH:—By whom was this engine produced?

COMMANDER GIBSON:—The German submarines revealed the fact that although it was a Machinenfabrik Ausburg-Nürnburg engine, originally built in Ausburg, the engine was farmed out to every Diesel engineering company in Germany.

C. F. SCOTT:—How does the fuel economy compare with that of the lower-speed types.

COMMANDER GIBSON:—The economy is very good. About 0.42 lb. per b.hp.-hr. is obtained at full power. That is not remarkable; it is good, and the combustion is good. We use every bit of the fuel in the cylinder. We ran a test generating 35 hp., just enough to overcome the friction loss of the engine. We had 35 hp. on the load, and we used 35 lb. of fuel. I do not know how it compares with the marine type engines that have been built for use in private vessels.

Side Guide and Gripper

Carburetion and Distribution of Low-Grade Fuels

By O. H. Ensign[1] (*Member*)

Semi-Annual Meeting Paper *Illustrated with* Photograph and Drawings

THE increasing difficulty of obtaining desirable fuel for automotive apparatus compels engineers to continue efforts to produce designs that will handle the continued lowering grade of fuel with the maximum economy. We are faced with a downward trend in production of stored fuel resources upon which the industry depends, so that it is now necessary and desirable that every effort be made to reach the highest economy from the standpoint of fuel consumption, with reference not merely to the dollars and cents operating cost of any individual apparatus, but from the standpoint of fuel conservation so that the industry may continue.

On the Pacific coast an intermediate grade of petroleum distillate, known as engine distillate, has been supplied the users of motor vehicles. This was midway between gasoline and kerosene in fuel quality. When the gasoline was of high grade, the engine distillate was a very desirable fuel comparable to present gasoline. During the past three or four years, engine distillate has fallen with the gasoline in grade as an automotive fuel, until its manufacture was abandoned by the principal oil companies early this year. At that time this fuel had an initial distillation point of about 240 deg. fahr. with an end-point of approximately 480, varying with the different producing companies. All of our efforts on the Pacific coast have been to handle such fuel efficiently.

Therefore, in designing it has been necessary to recognize the conditions imposed by the use of this fuel through the past five or six years, so that we were compelled to work out some of the problems in advance of the general lowering of the grade of all automotive fuels. In attacking this problem we have been forced to keep in mind certain essential features of economical design in connection with the carburetion problem. As we have seen these problems they have been

(1) An absolutely correct metering for all engine speeds and throttle positions in order that the proportion of air to fuel meets correct engine design

(2) The adaptation to changed engine design, especially in connection with the manifold, or more strictly speaking, the entire mixture path. In this connection fuel distributed evenly to all cylinders is of higher importance than limiting the manifold depression. The biggest loss in many designs has been in the fact that the cylinders were not pulling together

It should be realized from the outset that the lower the grade of fuel the more difficult it is to bring about even distribution and the more disastrous the results from poor distribution. There is one feature in poor distribution that has not been sufficiently discussed. That is the effect on fuel economy and the reason thereof. In the past carbureter designers have been attacking the problem by trying to reduce carburetion to fit the conditions of existing fuel distribution in current engine design.

For illustration, consider the ordinary four-cylinder engine. It has generally been constructed for truck or tractor work with two cylinders cast in block with a siamese valve pocket. In many cases the manifold and the siamese pocket have been considered as an ideal passage for a perfect gas. In reality it has to carry a gas which is transporting in suspension some vapor which may be considered similar to a gas and some spray which is far from being a gas. Such a manifold invariably results in performing the same function as a steam separator in steam engine practice; namely, separating the moisture, in this case fuel, from the air, causing the end cylinders to get the heavy ends of the fuel along with some of the light ends, while the middle cylinders will get only the light ends. In many cases the heavy charge to the end cylinders will be sufficiently vaporized in passing through the valves and by the heat of compression and hot cylinder walls, to burn without serious smoke or trouble. This has been shown many times in laboratory tests, where the mixture has been run 40 per cent richer than the chemically correct mixture without seriously affecting the power output.

The carbureter designer has undertaken generally to meet this condition by designing a carbureter which by changes of nozzle, multiple jets, chokes, tension of springs or by special cams, makes it possible to control the mixture with increasing load so as to bring the weak cylinders up to do their share of the work. In doing this while the power of the end cylinders has not seriously been interfered with, their charges have been enriched to a point where economy is lost.

The best way to bring about maximum economy, as well as maximum power, is to provide first a carbureter producing a mixture which meets the theoretical conditions of operation under throttle control with economy and flexibility, then to design manifolds that permit the use of this mixture by insuring even distribution to all cylinders.

A description will be given of a carbureter that has been in use for the last five years. The principle involved for metering the fuel and air in this carbureter is the drop in pressure that occurs at the center of a whirling mass of fuid. Fig. 1 represents a horizontal cross-section through the mixing chamber of the carbureter. Fig. 2 represents a carbureter assembly with a side-outlet throttle that has been largely used for tractor and truck engines. This metering element, shown as the vortex mixing chamber x, is unique in that it produces the desired mixture proportion without any compensating devices. From no load to full load, under throttle control or otherwise, it produces a mixture ratio of fuel to air with a gradual thinning of the mixture as the load goes on. This cannot be modified by the operator.

[1]President and engineer, Ensign Carbureter Co., Los Angeles, Cal.

Side Guide and Gripper

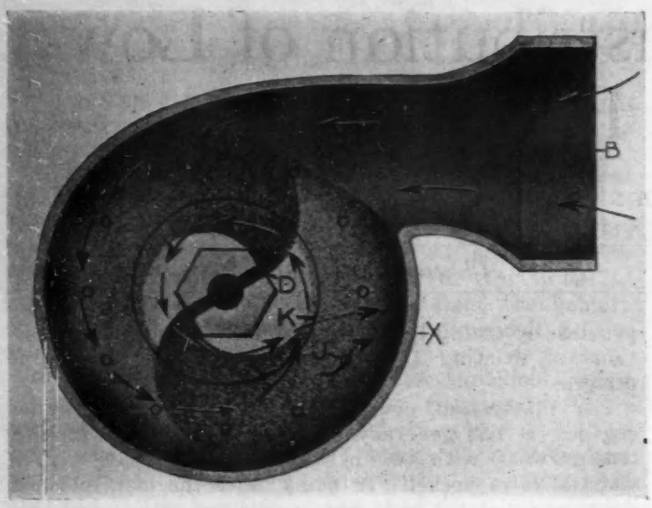


FIG. 1

The only adjustment that can be made is the adjustment of the size of the fuel orifice. This is a very simple device that is permanent in its performance and high in fuel economy.

The operation of this carbureter may be described as follows: The suction outlet *d*, in the center of the mixing chamber *x*, applies suction through the mixture passage *i*, into the chamber formed by the adjusting sleeve *g*. This suction draws the fuel through the submerged orifice *h* within this suction chamber, over the top of *i* to *d*, where it is drawn off by the whirling air. Since the revolutions about *d* run up to about 10,000 per min. at full load, extreme pulverization takes place. The orifice *h* is adjusted by the sleeve terminating in the milled head on *g*, this being the only fuel adjustment handled by the operator. A small air-valve in the top of the adjusting sleeve has a fixed setting and is open at all speeds above idling, so that the mixture is a little richer on idling than it is under load. With this valve open or shut at any adjusted position that will produce desired power results, metering tests show that it does not affect the metering characteristic of the vortex chamber. The balance tube *j* supplies air from the air horn to the surface of the fuel in the float chamber and to the small valve in the adjusting sleeve, so that whatever may be the resistance in front of the carbureter imposed by a stove or air clarifier, the mixture proportion is dependent solely upon the centrifugal force of the whirling air around *d*. The rest of the carbureter needs no further explanation except as shall come out in discussion of its performance. There have been several types built around this general design which will be illustrated later.

It will be noticed that the air horn of this carbureter is a low-velocity, high-efficiency nozzle in form, so that the pressure drop through this air horn may be taken quite confidently as a means of metering the air flow for purposes of comparison. It will be shown that this assumption is correct and that air friction is almost entirely eliminated both in the air horn and in the mixing chamber. Fig. 3 shows pressure-drop curves developed to illustrate how this vortex mixing chamber functions. The lower line, which designates depression in the air horn, was drawn in and the speed of the engine adjusted until the desired depression was obtained on this line at each one of the different readings numbered along the abscissæ. The corresponding reading was then taken for the depression on the mixture orifice. No air was allowed to flow through the fuel orifice in plotting the middle curve, which was taken with the mixing chamber set on a box that was connected with an exhauster. The natural pressure drop characteristics of the mixing chamber alone were thus developed since nothing but air passed through the apparatus without any interference

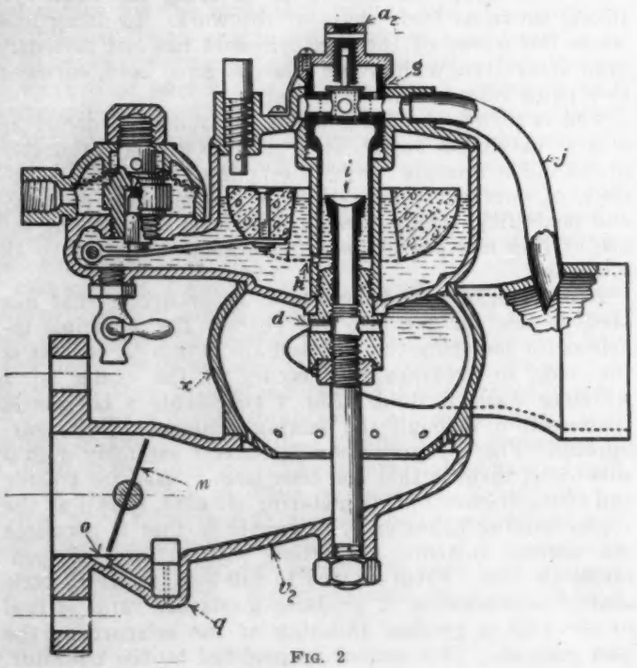


FIG. 2

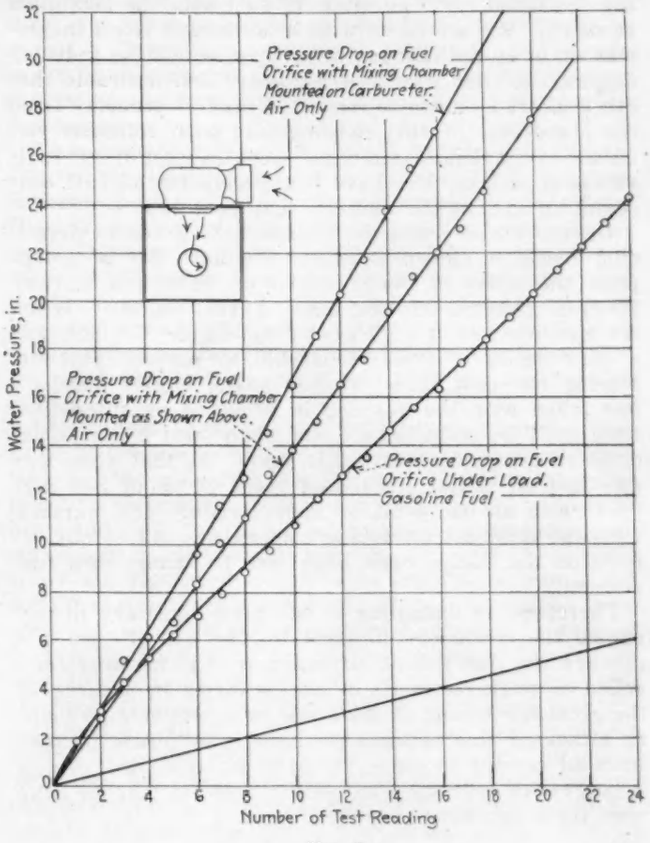


FIG. 3

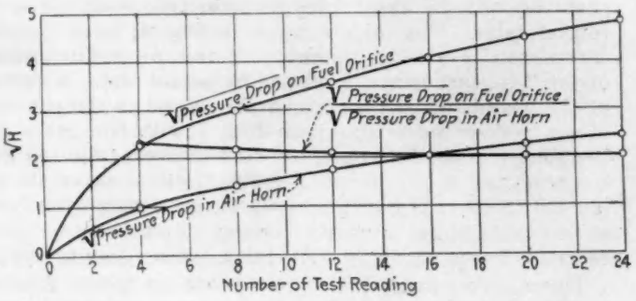

√Pressure Drop on Fuel Orifice
√ Pressure Drop on Fuel Orifice
√ Pressure Drop in Air Horn
√Pressure Drop in Air Horn
√H
Number of Test Reading

FIG. 4

from any other part of the carbureter. It will be noticed that the readings thus obtained follow a straight line very closely and that the curve of the vortex pressure drop is just five and a half times the drop of pressure in the air horn, even up to the highest reading. This constant ratio indicates that there is no appreciable friction in either the mixing chamber or air horn and that the air horn pressure drop is a safe indication of air velocity. The top curve was taken with the carbureter assembled as in Fig. 2 with air only, no air flowing through the fuel orifice, the pressure drop being that in the suction chamber within the adjusting sleeve. Here it will be noticed that there is a peculiar shape to this curve and that the ratio is much higher and not constant, increasing with the velocity. The lowest curve was taken with the same apparatus mounted on a six-cylinder 4⅛ x 5½-in. engine and adjusted for the same pressure drop for each reading in the air horn. The pressure drop on the fuel orifice was taken with the carbureter functioning in a normal manner. Here we find a change in the pressure-drop ratio between the air horn and the fuel orifice, which shows a leaner mixture as the load goes on.

In Fig. 4 the two curves are plotted respectively from the square roots of readings of depression in the air horn, and of curve on the fuel orifice as indicated in Fig. 3. The ratio of the two curves which indicates the tendency to thin the mixture from no load to full load is also plotted.

The mass of air within the vortex mixing chamber is practically constant at all speeds and loads and must be considered as a freely rotating flywheel of air, flexibly impelled, which functions the same as a centrifugal pump impeller. It can readily be seen that fuel delivered at the suction outlet *D* has work performed upon it in

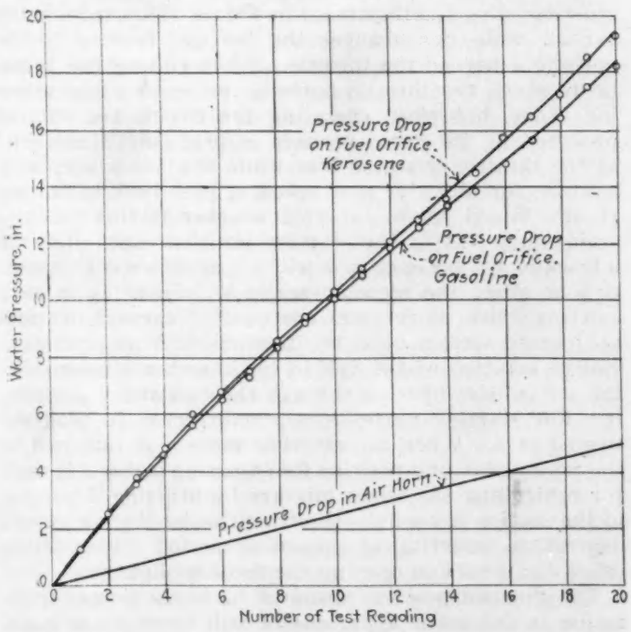

Pressure Drop on Fuel Orifice. Kerosene
Pressure Drop on Fuel Orifice. Gasoline
Pressure Drop in Air Horn
Water Pressure, in.
Number of Test Reading

FIG. 5

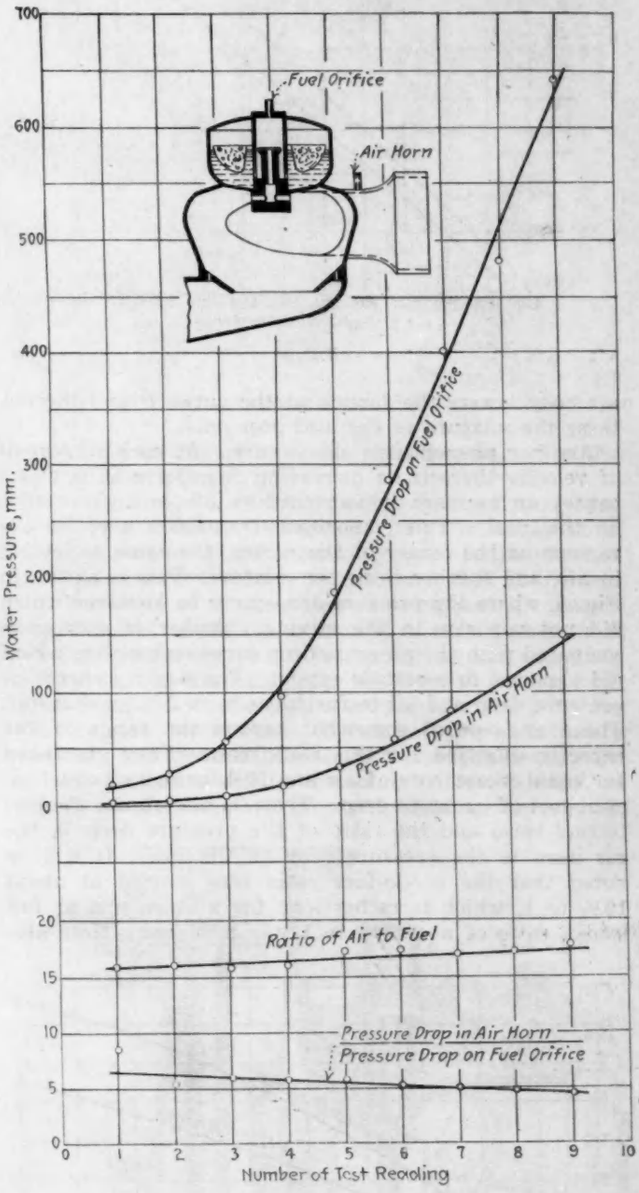

Fuel Orifice
Air Horn
Pressure Drop on Fuel Orifice
Pressure Drop in Air Horn
Ratio of Air to Fuel
Pressure Drop in Air Horn
Pressure Drop on Fuel Orifice
Water Pressure, mm.
Number of Test Reading

FIG. 6

being brought up to the velocity of the air by the action of this whirling air body. The energy thus imparted to this fuel at any instant of time to bring it up to each new air velocity with each new quantity of fuel, is taken from the freely rotating fixed mass of air in the mixing chamber. The increasing amount of fuel delivered at each increase of load tends to cause the speed of this mass of rotating mixture to lag increasingly behind the clear air speed. This lagging of the revolutions of the

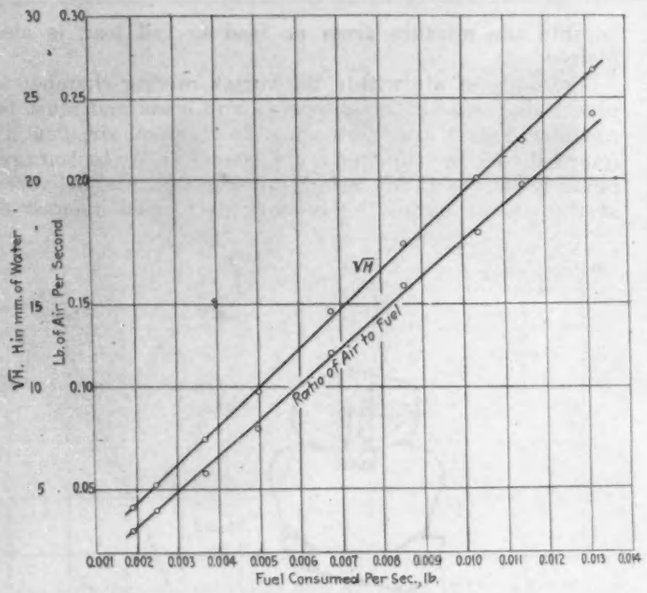


FIG. 7

air body lowers the suction at the outlet D and thereby thins the mixture as the load goes on.

Another phenomenon also occurs. At each increment of velocity there is an increasing depression at D which causes an increase in vaporization of the lighter ends of the fuel. This vaporization satisfies part of the vacuum at the center of the vortex, the same as letting in air, and further thins the mixture. This is shown in Fig. 5, where the pressure-drop curve on kerosene which did not vaporize in the mixing chamber is shown, as compared with the pressure-drop curve on gasoline which did vaporize to a certain extent. Fig. 6 gives curves of pressure drop and air-to-fuel ratio on a 2-in. carbureter. These are carried somewhat beyond the range of the capacity intended for this carbureter. They are taken for equal increments of air and fuel instead of equal increments of pressure drop. There is also shown the air-to-fuel ratio and the ratio of the pressure drop in the air horn to the pressure drop on the fuel. It will be noted that the air-to-fuel ratio was started at about 15½ to 1, which is rather lean for a start, and at full load a ratio of about 17 to 1 was produced. Note also

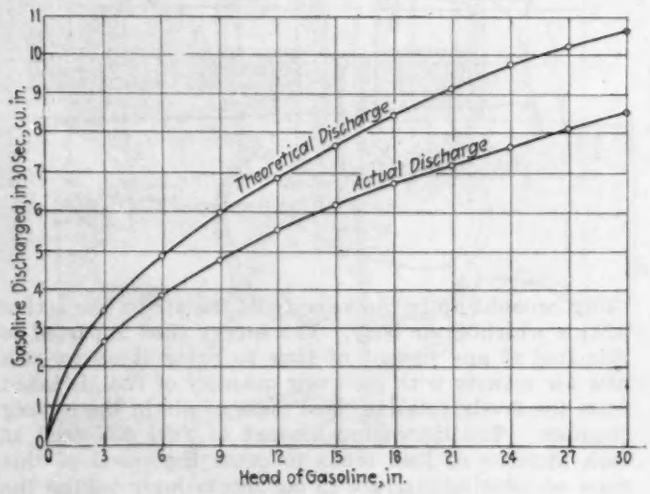


FIG. 8

that the ratio of the curves is consistent with the air-to-fuel ratio. The middle curve in Fig. 4, on a 1¼-in. carbureter, is also consistent with this air-to-fuel ratio of the 2-in. carbureter developed by actual test. A curve of the pounds of fuel consumed per second to the pounds of air per second is shown in Fig. 7 with the curve of the square root of H upon the fuel orifice as figured by the readings of Fig. 6. Fig. 8 illustrates a curve showing the theoretical and actual discharge through the fuel orifice, indicating a nearly constant coefficient of discharge. These readings were taken under gravity head.

These curves bring out some interesting facts. A carbureter designed in this manner, using a vortical pressure drop instead of a choked passage for metering, follows closely in operation the simple general formula

$$V = \sqrt{2gH}$$

for air and fuel flow. This results from the fact that the design recognized this law in its inception and adhered all the way through to the conditions necessary to allow the undisturbed operation of it. This law cannot be followed unless friction is eliminated from the start of the air flow up to where it affects the fuel pressure, and friction and capillary action are eliminated from the fuel orifice. The air horn is wide-open, of about manifold size, and of a normal contraction, giving practically no friction. The mixing chamber is built along similar lines. The fuel orifice is a submerged hole in a thin wall which has an unusually constant coefficient of discharge. This design results in a straight-line mixture which is richer in fuel at low-speed throttle control than at full load and gives the desired flexibility and economy under varying load.

Referring to the gasoline and kerosene curve, Fig. 8, the kerosene which does not vaporize calls for a higher pressure drop in the same carbureter on the same fuel orifice than gasoline. This demonstrates that as the cold weather comes on with a mixture that has been set for summer, the gasoline, tending to vaporize less in the cooler air, will naturally enrich the mixture slightly to compensate for the changing in temperature. This correction for temperature is quite marked.

A form of this carbureter which is supplied with a starting valve a is illustrated in Fig. 9. This valve being thrown wide-open changes the fuel jet from d to the opening o beyond the throttle. When closing the throttle to start, the throttle butterfly m becomes the starting choke, but when operating the engine the suction produced by its closed position is gradually diminished as the throttle opens, so that while it gives a very rich mixture for idling or slow speed, it goes back to normal at any loaded speed. In cold weather if this valve is accidentally left in the starting position indefinitely on a truck or tractor engine, it will not interfere with operation or affect the economy seriously. In using it as a starting valve, it reverses the current through d, puts an intense suction upon the fuel orifice h and causes a violent aeration of the fuel in the chamber c because of the air bubbles blowing through the fuel and vaporizing it. For starting purposes, a strong spray is thus delivered at o. When the starting valve a is returned to the normal running position its adjusting screw e is used for controlling the idling mixture by utilizing a portion of the suction beyond the throttle to assist the low vortex depression occurring at the idling period. This idling effect disappears on opening the throttle slightly.

The greatest problem ahead of us is the proper utilization in automatic apparatus of still lower-grade gasoline than used at present and efficient use of the kero-

senes. The splendid work done by some of the manufacturers of kerosene engines, who have had foresight enough in the past to undertake seriously the development of such an engine for tractor and other uses, must not be lost sight of, as there has been much success along that line. However, there are very many engines in existence that have to meet the lowering grades of fuel and it is an exceedingly difficult matter to do it without a radical departure from usual carburetion methods. To meet this demand there has been developed what is called a fuel converter. This device attacks the problem of extremely low-grade fuel from a new angle. It essentially consists of a carbureter or metering system, a gas producer and a thermostat combined with starting means. Its operation consists of separating by gravity and suction the heaviest ends of the fuel into a combustion chamber where they are ignited, the flame being extinguished by suction before complete combustion. The hot products of this partial combustion are added to the lighter ends of the fuel, which by-pass this combustion chamber and the heat released by the partial combustion of a portion of the heavy ends vaporizes the remainder of the fuel. The inert or slow-burning gases produced by the combustion chamber assist very materially in preventing the knock which always accompanies kerosene under high compression, making it possible to use a much higher compression for such fuels than could otherwise be employed.

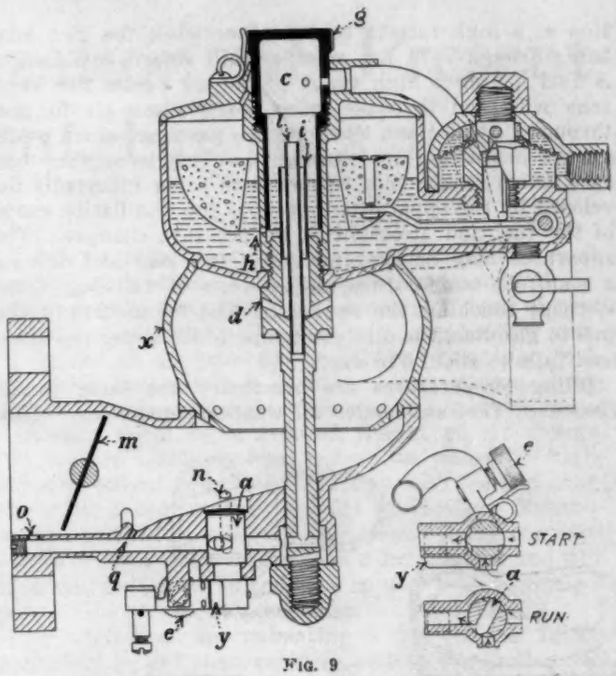


FIG. 9

FUEL CONVERTER

Fig. 10 shows this apparatus. The general mixture passage, metering system, adjusting means, and throttle are similar to the standard carbureter. In the floor of the mixture passage is constructed the fire screen *u*, through which the heavy ends of the fuel fall upon the distributor *c*, where they are mixed with some air so that a very rich mixture exists in the annular space between *c* and the roof or the combustion chamber. This fuel is ignited by the spark-plug shown producing a downward whirling flame which is drawn upward through the gas flue *z*, extinguished and delivered past the throttle. At this point the hot gaseous products of the carbureter combustion chamber mingle with the other portions of the mixture that have by-passed it. A small amount of gasoline, about 1 cu. in., is supplied to the starting chamber *e* for starting. It overflows and falls into the sump underneath the flue *z*. Cranking the engine with throttle closed will draw the gasoline from this sump up through the flue *z*, since the notch *o* in the throttle disk is open, starting the ordinary automobile or truck engine in that manner. As soon, however, as the engine starts, combustion begins in the carbureter base, ignited by the spark in the combustion chamber, and the gasoline continuing to flow through *f* assists in maintaining combustion until the walls become warm enough to handle straight kerosene. The temperature will rise rapidly; in fact, in cold weather manifold temperatures of 190 deg. fahr. can be obtained in 1 min. after starting. As the apparatus warms up, vaporization will take place from the floor of the mixture passage *l* and from the outside of the flue *z*, so that only the very heaviest ends will pass through the screen *u* and into the combustion chamber. After getting very hot the rapid distillation of these heavy ends on the surface of *c* more or less checks the flow into the combustion chamber by expansion and holds down the load temperature, so that with the throttle wide-open the load temperature on kerosene is about 180 deg. fahr. The engine can be put to work as soon as started and on kerosene will attain full flexibility in any weather in a fraction of the time that any other device will on gasoline.

The air by-pass *v* is incorporated to compensate for weather conditions and grades of fuel. It draws from the upper portion of the mixture passage *l;* therefore in starting when everything is cold and fuel is flowing along the floor of *l*, practically nothing but air passes through *v*, thus building up rapidly a very high rate of combustion. As the apparatus warms up and vaporization begins to take place from the floor of *l*, some mixture will pass down through *v* and smother the fire, lowering the load temperature. It can be easily seen that in extremely cold weather the amount of fuel passing with the air through *v* will be less than in hot weather, so that the air passing through *v* will build up the combus-

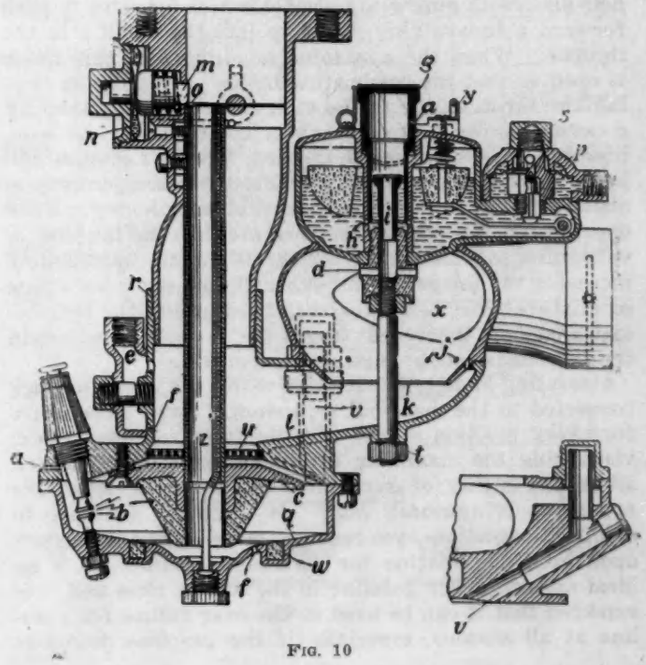


FIG. 10

tion at a high rate in cold weather while the rich mixture through *v* in hot weather will retard combustion. A fuel having a high range of boiling points like kerosene will tend to cause more nearly clear air to pass through *v* at all times than one like gasoline, which would always put a mixture through *v*. This is another feature which results in a temperature being inherently developed by the apparatus that suits the distillation curve of the fuel and atmospheric temperature changes. The apparatus may be running under full load and develop a manifold temperature on kerosene of 180 deg. fahr. Without touching the apparatus and by switching the fuel to gasoline, the mixture temperature under the same load falls to about 115 deg.

Idling temperatures are practically the same on all classes of fuel and under all weather conditions. This

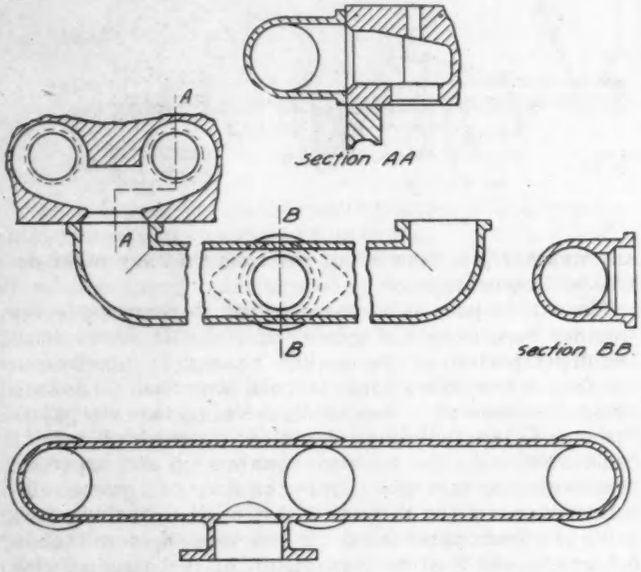


FIG. 11

temperature is controlled by the thermostat capsule *n* half-filled with pure grain alcohol, which operates to push forward a square plug *m* fitting into the notch *o* in the throttle. When the apparatus is idling cold this notch is open so that the combustion builds up rapidly on closing the throttle, due to the violent forced draft through *o* caused by the depression above the throttle. As soon, however, as it approaches 180 deg. fahr. the plug *m* will begin to close the notch *o*, regulating the temperature to about 230 deg. fahr. for continued idling running. Upon opening the throttle the temperature falls and the plug *m* withdraws so that closing the throttle again immediately increases the temperature. A small duct provides a flow of mixture from below the throttle, through the thermostat chamber, thence out above the throttle to maintain the thermostat at the mixture temperature.

Operating an automobile fitted with a dash thermometer connected to the manifold, will show a new temperature for every position of the throttle from full load down, visualizing the maximum flexibility, quick starting and all-around utility of kerosene. The economy with this apparatus is unusually high. It is not so sensitive to manifold conditions, yet remains more or less dependent upon good distribution for maximum results. It is an ideal apparatus for gasoline in the winter time and it is expected that it can be used in the near future for gasoline at all seasons, especially if the gasoline decreases in grade. The ideal fuel for it is one with an initial distillation point of 300 and an end-point of 550 deg. fahr., with which it develops equally as much or more power than with gasoline, but it works satisfactorily on a fuel with an initial distillation point of 350 and an end-point of 650 deg. fahr. With either of these fuels there is absolutely no fire danger, but with a high-grade gasoline in the summer time, the mixing chamber *x* will carry the heat from the converter body up to the float bowl, and with the added heat under the hood, tend to cause vaporization from the float-chamber. If a back-fire then occurs there is the same risk of this vapor being ignited as occurred when high-grade gasoline and ordinary carbureters were used. However, with the spark-plug disconnected, it is an excellent operating carbureter on the present gasoline, in the summer time, and gives very satisfactory results. With this apparatus we are endeavoring to meet the fuel condition on the Pacific coast, imposed by the abandonment of distillate, and it is now operating satisfactorily with kerosene on many installations of truck, tractor and marine engines even up to a bore of 9¾ in. and a 12-in. stroke, at speeds as low as 280 r.p.m., giving high economy and satisfactory operating results. This carbureter has been on sale for two years.

MANIFOLDS

Referring again to the subject of manifold designs, there has been much discussion in the past about the question of dry and so-called wet mixtures. With the range of boiling points involved in the fuels which can be used in automobile, truck, tractor and marine engines, if we endeavor to obtain a perfectly dry mixture the temperature of the mixture becomes so high that it seriously affects the efficiency of the engine. If, on the other hand, a cooler mixture can be used by accomplishing as nearly as possible perfect distribution to all cylinders, several advantages are gained. One is a greater power output per unit weight of the engine. Another is a very great reduction of the tendency to knock on the heavier fuels. To accomplish this distribution every elbow, every tee, every branch of any sort must be studied with regard to its tendency to separate the fuel from the air, and correction of some sort must be made.

Take the simplest form of manifold in use, a plain elbow to fit a carbureter to an engine with the manifold cast in block. Decided increases in power, flexibility and some change in fuel economy, have been made upon many engines by simply changing from a long-sweep elbow to one of uniform cross-section, but with the inner bend a right angle, similar to the elbows shown in Fig. 11. This has never failed to be the result when any low-grade fuel is used; in fact, an improvement is shown on all fuels available at the present time. Passing through the long-sweep elbow, centrifugal force throws all the fuel to one side. With this sharp elbow sufficient agitation is created to carry on a remixing effect beyond the elbow. Even so, this elbow is again in many cases improved if a small choke at a 45-deg. angle is added where it bolts on the block.

An ideal type of manifold for safe distribution without excessive mixture temperature is illustrated in Fig. 11. This is not theoretical but has been proved over and over again. The type of branches shown between the vertical riser from the carbureter to the main manifold, the type of distribution to the individual cylinders, and the design of the siamese valve-pocket and approaches to it around the elbow, have all been proved out as advan-

(*Concluded on page* 50)

Report on the Utilization of Present Fuels in Present Engines

AT the Fuel Session of the Semi-Annual Meeting of the Society, held June 22 at Ottawa Beach, Mich., the committee which has been considering the question of the utilization of present fuels in present engines presented the accompanying report. This deals with one phase of the subject, the application of heat to secure the desired end, and is more in the nature of a progress report than one giving the final recommendations of the committee. Other reports dealing with different methods will, it is expected, be presented from time to time. It is pointed out that all who contemplate following any of the committee's recommendations should first investigate the patent situation, as many patents purporting to cover various means for obtaining the advantages here spoken of have already been issued, and doubtless similar applications are pending in the Patent Office.

The Report

THIS report is intended to be a guide in burning the more or less volatile fuels, known as gasoline, in old and present engines, and may be an aid in bringing out new engines.

Every effort has been made to gather authoritative information as to the methods of burning gasoline more efficiently.

It is the conviction of the committee and those whose criticism has been of inestimable aid in working out the report that the very life of the industry depends upon the adoption of some better means of vaporization and distribution. The method suggested in this report is one of several means whereby better vaporization may be accomplished. It has been chosen as the subject of this report because of its simplicity and ease of application.

This report will be amplified from time to time. In its present form it constitutes the essential features of the information available to the committee.

The report applies particularly to the preparation of mixtures from fuels of a wide range of volatility such as must be considered by the designer of engines and carbureters today. Up to the time that fuels of lower end-points than 302 deg. fahr. became uncommon, vaporization was not a difficult problem.

Modern carbureters are considered as being sufficiently accurate metering devices. With the heavier fuels commonly available, the heat accidentally available in carbureters, manifolds or from the combustion chamber walls is adequate for vaporization of the fuel under all conditions.

No general formula for the solution of a problem with so many variables, such as this, can supersede the judgment of an engineer. However, if engineers will work out the intake designs and apply the principles of design laid down in this report and temper each decision with judgment, marked improvement will result in the operation and service of any motor car or truck.

The report, therefore, centers on the preparation of proper combustible mixtures from the less volatile gasolines and involves consideration of questions of vaporization and distribution.

Types of Mixtures

A dry mixture gives the best distribution and most complete combustion. With increasing end-points of distillation for the fuels there is an increasing need of heat application. Attempts to attain a thoroughly dry mixture under all temperature conditions with high end-point fuels may result in so high a temperature of the mixture that an appreciable decrease in maximum power is brought about by a reduced weight of air charge. With fuels of relatively high end-points, where the highest power output is desired consistent with the fuel characteristics, a fog mixture permits of excellent distribution and practically perfect combustion. A fog can exist at a much lower temperature than a dry mixture and will, therefore, permit of an increase in power by allowing a greater charge weight per stroke.

One method of approximating a fog consists in the application of sufficient exhaust heat to the limited sections of the inlet manifold at which there is a maximum separation of the liquid fuel from the mixture stream. The liquid separated from the airstream is thereby vaporized by the hot surface and is then condensed in the mixture stream in the form of a fog.

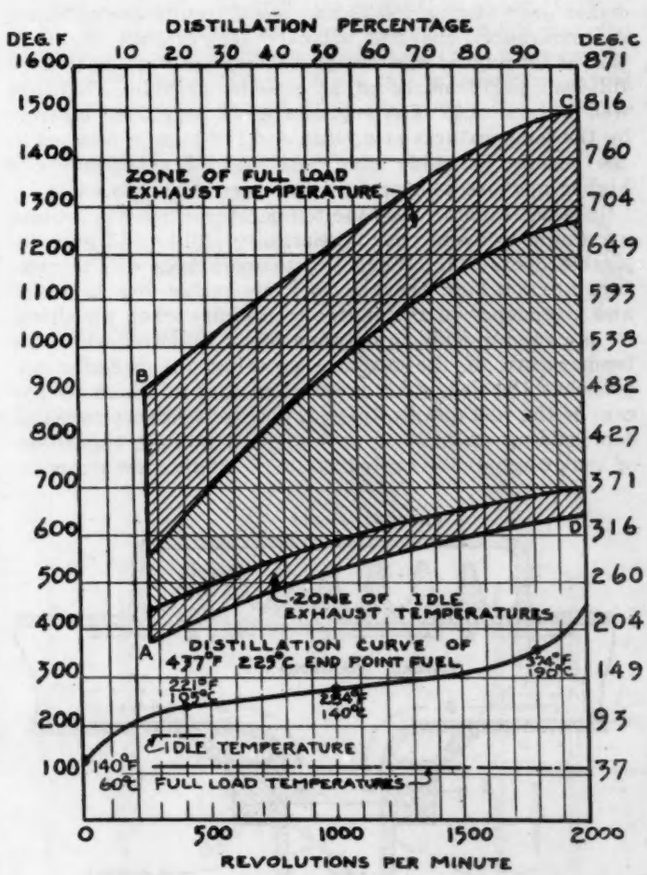

DISTILLATION PERCENTAGE
DEG. F
DEG. C
10 20 30 40 50 60 70 80 90
1600 1500 1400 1300 1200 1100 1000 900 800 700 600 500 400 300 200 100
871 816 760 704 649 593 538 482 427 371 316 260 204 149 93 37
A
B
C
D
ZONE OF FULL LOAD EXHAUST TEMPERATURE
ZONE OF IDLE EXHAUST TEMPERATURES
DISTILLATION CURVE OF 437°F 225°C END POINT FUEL
221°F 105°C
284°F 140°C
334°F 190°C
IDLE TEMPERATURE
140°F 60°C
FULL LOAD TEMPERATURES
0 500 1000 1500 2000
REVOLUTIONS PER MINUTE

FIG. 1

Mixture Temperatures

Fig. 1 represents the composite result of a number of typical tests in which mixture and exhaust temperatures were measured. At 250 r.p.m. and full load the exhaust temperature runs from 600 to 925 deg. fahr.; at 1000 r.p.m. from 1025 to 1225 deg. fahr. and at 2000 r.p.m. from 1300 to 1500 deg. fahr.

At 250 r.p.m. with no load the exhaust temperature is seen to be 400 to 450 deg. fahr. After long periods of idling it may drop 50 deg. below this. At 1000 r.p.m. it is 550 to 625 deg. fahr. and at 2000 r.p.m. it is 650 to 725 deg. fahr. Thus all variations of speed and load result in exhaust temperatures within the zone *ABCD* shown in Fig. 1.

Readings taken with mercury thermometers and pyrometers in the intake manifold are apt to be misleading on account of the wet condition of the mixture. The bulbs or thermocouples give wet-bulb readings which are too low. Just above the throttle there is a drop in temperature below that of the air entering the carbureter due to the vaporization of the lighter constituents of the fuel and the depression in the intake. When the mixture strikes the heated surface the fuel separates and vaporizes.

Readings of temperatures of mixtures entering the cylinder ports have been found to indicate that mixtures should have a temperature at full load varying with the distillation curve of the fuel. It will be found that if the temperature of the mixture entering the cylinder during full-load performance is about 150 deg. fahr. lower than the temperature at which 50 per cent of the fuel comes over during distillation, good results are attained. A remarkably constant mixture temperature is maintained by any of the designs shown in Figs. 2 to 6 at full-load performance at all speeds, provided they are well worked out. The engineer must be guided entirely by the temperatures at no-load and full-load in relation to the results to guide him. At no-load performance a higher mixture temperature has been found to exist.

It is desirable to keep the temperatures below a certain maximum to avoid poor accelerating ability and give desirable operation. When the temperatures of the mixture are too high there is very noticeable loss in power and a tendency of the engine to backfire when the throttle is closed quickly to extreme idle. Likewise when the temperature of the mixture entering the cylinder approaches 190 deg. fahr. lower than that at which 50 per cent of the fuel distills, there is decided tendency to manifold loading on hills or at low-speed pulling, regardless of the design of the heated surface. At this low temperature limit the influence of the cooling water temperature is of major importance. The values given above for mixture temperature conditions apply to best mixture proportions and atomization.

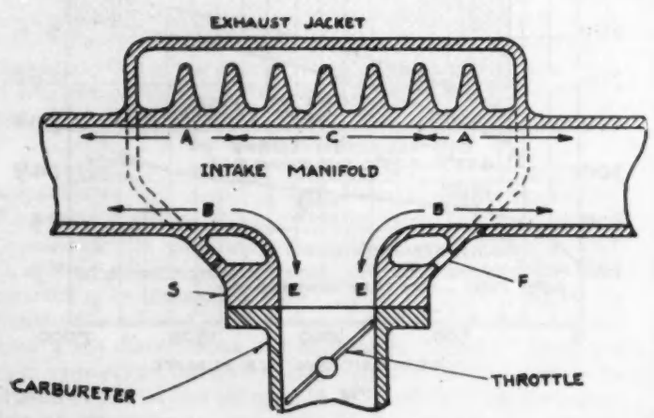


Fig. 2

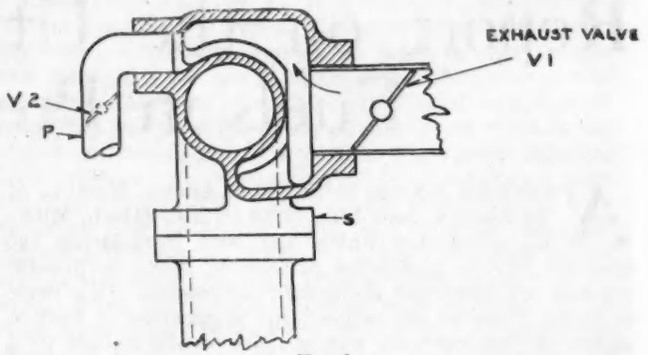


Fig. 3

The lower grades of gasoline of course require a higher mixture temperature and more heat at the hot surface; hence larger heating areas are necessary. However, judging by a report recently issued by the Bureau of Mines, it appears reasonably certain that the petroleum industry can for the next three years provide fuel corresponding to the distillation curve shown in Fig. 1. So far as this fuel is concerned it would be wise to design apparatus to give a mixture temperature of 127 deg. fahr. under all weather conditions. While this will give a hotter mixture than necessary for lower end-point fuels, the fuel generally available should govern the design.

Design of Manifolds, Condensation of Fuel and Application of Heat

Fig. 2 shows one type of heated-surface manifold. The object of this design is to provide a means of heating the liquid thrown out of the airstream, with the least possible heating of the air itself. At slow speeds of the mixture the tendency is for the fuel to collect on the wall of the vertical section of the manifold and at the inside corner of the bend *B*. At higher speeds the tendency is to collect in the horizontal part of the manifold. At higher speeds the liquid fuel strikes the manifold at *C* and alternately at *A-A*, reaching points farther from the intersection as the speeds increase.

The amount of liquid fuel usually deposited can be vaporized on a comparatively small area of the heated surface and it is impossible to heat this surface so hot by the use of exhaust as to crack the fuel or ignite the mixture. However, if the wetted surfaces at points *A*, *B*, *C* and *E* are all heated, the mixture may reach unsatisfactory temperatures.

It has been found of advantage in some cases to reduce the heating surface in an intake tee branch by resorting to jacketing as indicated by Fig. 3, in which one side only is exposed to the exhaust flame. A satisfactory result has been obtained with this jacketing when the exhaust jacket is connected to the exhaust manifold by a pipe which is not over 6 in. long. A valve for controlling the quantity of exhaust gas passing through the jacket is strongly recommended with this design, to enable an adjustment for seasonal and atmospheric changes and for fuels varying in volatility.

The carbureter should be close to the heated section of the manifold. Since the throttle causes a separation of the fuel from the airstream, it should be placed so as to minimize this effect and interfere least with the distri-

bution. The best practice is to make the intake manifold short.

The vaporizing of fuel from a hot surface by exhaust heat is accomplished best by producing as high a surface temperature as possible. The limiting factors are the temperature of the exhaust, the velocity of the exhaust gases, the extent of the surface presented to the exhaust flame, the conductivity of the metal and the amount of deposited liquid fuel. The liquid fuel is in contact with the heated surface for so short a time that it is necessary to have high enough temperatures to vaporize fuels of high end-point quickly, and to supply sufficient heat to maintain these temperatures of the hot surface. The temperature of the exhaust and the heat available drop rapidly after the gas leaves the exhaust port.

The temperature of the mixture side should rapidly follow changes in the demands upon the engine. The surface must attain its temperature quickly in warming up and when changing from a full-load to an idle condition should quickly cool off. The heating surface should therefore have as small a capacity for retaining heat as possible; hence it should be of thin section. With too heavy a heated section, one in which the heat capacity is high, there is a tendency for the acceleration to be poor after a heavy pull.

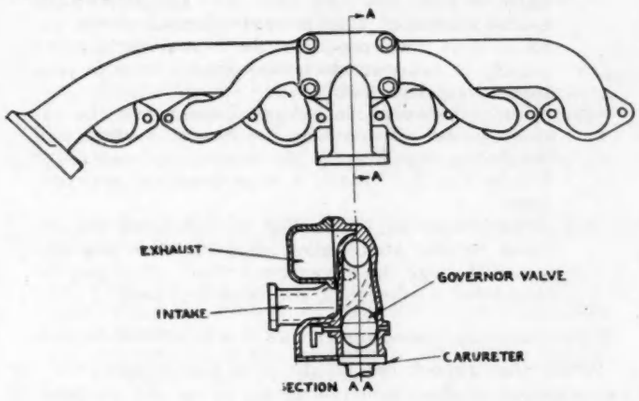


FIG. 4

Fig. 4 shows the manifold on the Class B military truck engine, which produced satisfactory results. This is an example of a simple way of conducting heat at high temperatures to the mixture, but it lacks the means for an adjustment for seasonal or atmospheric changes of temperature, and may be found to be subject to certain defects listed in the above paragraphs. Seasonal adjustment can be accomplished by varying the heating of the air entering the carbureter.

Fig. 5 illustrates an elbow construction for hot-surface manifold work. There are two areas, *A* and *B*, where fuel separation occurs. Slow speeds require heat at *B;* higher speeds call for heat at *A*. The hot surface can therefore be concentrated at these points with the least area for all conditions.

The upper portion of Fig. 6 illustrates an application of exhaust to engines where a long vertical intake pipe separates the carbureter from the branch. The two views in the lower portion show sections of this vaporizing device.

When an intake is jacketed separate from the exhaust, as in Fig. 3, it is necessary to see that the jacketed portion is not a dead end but forms a passage for the exhaust. This is accomplished by providing an outlet *P* which need not exceed ¾ in. in diameter if noise is

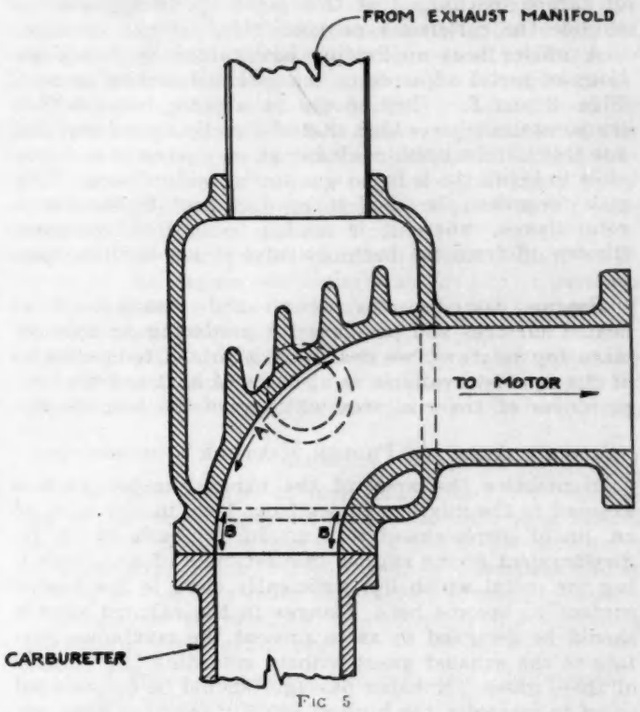


FIG. 5

a controlling factor. It is possible to locate this exit so as to localize the heat in certain spots. It may be found very effective also to drill two holes *F* as shown in Fig. 2, to the atmosphere at points opposite *B* so that the exhaust will flow to these points and thus improve the performance when idling. When this is done care should be taken to avoid danger from fire should hot particles

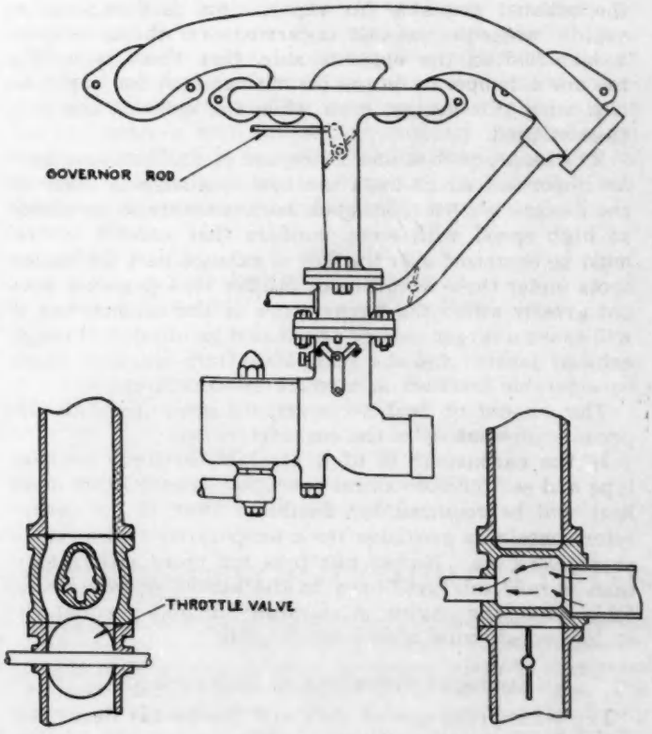


FIG. 6

of carbon discharged at this point ignite any gasoline outside the carbureter or manifold.

A milder heat application is obtained by heavy sections of metal adjacent to the jacketed section as at *S*, Figs. 2 and 3. They should be avoided because their temperature is lower than that of directly heated surfaces, but they can be used to advantage *only* when it is impossible to bring the exhaust gas to the desired spot. They may frequently be used to conduct heat to the carbureter flange, where it is needed because of the spray thrown off from the butterfly-valve at low-throttle opening.

Having described the design and arrangement of heated surfaces and passages for producing an approximate fog mixture, we deal next with the temperatures of the exhaust available as a source of heat and the temperatures of the mixtures which give the best results.

Surface Area for Proper Mixture Temperature

In practice the area of the exhaust-heated surface exposed to the mixture varies from 1 sq. in. for each 15 cu. in. of displacement to 1 sq. in. for each 30 cu. in. displacement of the engine, this estimate of area including the metal which lies sufficiently close to the heated surface to become hot. Flanges in the exhaust stream should be designed so as to present the maximum surface to the exhaust gases without retarding the velocity of these gases. Exhaust passages should be constructed so as to maintain the highest velocity over the heat collecting fins and yet not impose detrimental back-pressures.

When the exhaust gases just leaving the port impinge upon the heated surface the least area per cubic inch displacement is required. When the exhaust is 12 in. or more from the hot surface, the larger area is required. The quantity of the exhaust gases in such a case must not be less than that conducted by a pipe having the same sectional area as the intake passage. The heat in the exhaust available for vaporization is dissipated so rapidly when the exhaust is carried over the cylinder to a manifold on the opposite side, that there is usually too low a temperature and insufficient heat for vaporization with this design, even when the entire exhaust is then utilized.

The back-pressure due to the use of mufflers may have an important effect upon the heat available in some of the designs shown. So much back-pressure is developed at high speed with some mufflers that careful control must be exercised over the flow of exhaust past the heated spots under these conditions. Muffler back-pressure does not greatly affect the temperature of the exhaust but it will cause a larger volume of exhaust gas to flow through exhaust jackets and the vents therefrom and thus cause considerable increase in mixture temperatures.

The amount of heat necessary for good operation depends somewhat upon the carbureter.

If the carbureter is of a straight uniform mixture type and set for economical operation, considerably more heat will be required for flexibility than if the carbureter contains a provision for a temporarily rich mixture on acceleration. Richer mixtures are more satisfactory than normal mixtures even in the heated-surface manifolds while the engine is warming up and particularly at low speed with wide-open throttle.

Service Conditions to Be Satisfied

The widespread use of cars and trucks has developed a broad range of conditions under which the engine must operate. The following are among the conditions which must be met by manual adjustment of temperatures of the mixture by regulating the exhaust flow to the heated surface, or otherwise:

(1) The temperature under the hood may vary from 0 deg. fahr. in winter to 150 deg. fahr. in summer
(2) The variation between day and night temperatures
(3) The wide variation in temperature due to latitude
(4) Variations due to altitude and barometric changes

Most of the above conditions can be successfully met so far as adequate heat is concerned by using care in the design of the manifolds so as to admit adequate exhaust to the heated surface, for sea level and coldest service, and by providing valves so well made as to cut off part or all of the exhaust to the heated surface for altitude and hot-weather service. This latter condition is particularly necessary when a high back-pressure is developed by the muffler. In one case on record a temperature of over 600 deg. fahr. was observed at the hot surface in spite of the fact that the exhaust throttle was only cracked.

Valves may be used in three locations to regulate exhaust flow, as follows:

(1) A valve to close the main exhaust passage partially or fully and thus force the exhaust over the heated surfaces. This is used when all of the exhaust is at times needed at the heated surface and usually in cases in which the exhaust must be conducted long distances
(2) A valve between the exhaust header and the exhaust jacket surrounding the heated surface and regulating the flow to the heated surface, as at *V*-1 in Fig. 3. This is a most practical arrangement
(3) A valve such as *V*-2 in Fig. 3, regulating the exhaust to the atmosphere after the hot gas has passed through the exhaust chamber. This may be considered a refinement and is seldom used

Fundamental Considerations Affecting Economy

While this report has to do with the preparation by vaporization of the explosive mixtures for the purpose of effecting a satisfactory and economical service from our present fuels, the engineer must keep in mind the other fundamental considerations affecting economy. Below attention is briefly called to these factors with suggestion that they be constantly consulted and their importance never overshadowed by any non-essential treatment.

The air standard efficiency established by the Gaseous Explosion Committee of the Royal Society as the most fundamental method of comparing results and expected performances from internal-combustion engines, points out the importance of compression ratios as the method through which we may expect high power and economy from a given engine.

It is therefore important that the engineer shall keep in mind those things which limit the compression ratio in designing the engine or tend to reduce the actual compression in service. Among these considerations the following are important:

With present fuels compression is governed by such fuel characteristics as tend to allow such a rapidity in flame propagation as to produce the phenomena known as "ping pinking," knock or detonation. This limits the compression ratio by making the engine appear rough and thus both power and economy are limited.

The mixture temperature at which an engine will knock due to detonation depends primarily on the fuel.

Generally speaking, fuels with contents having boiling points over 350 deg. fahr. are susceptible to detonation with compressions running over 70-lb. pressure.

Engines have the strongest tendency to detonation when volumetric efficiency is highest, i.e. at the slower speeds. This fact determines the compression permissible in any design. If an engine is susceptible to carbon deposit due to overlubrication, it will take very little heating of the mixture to cause knocking. In the case of engines designed so as to have low turbulence of the charge and poorly designed water-jacketing and cooling of the piston or other parts of the combustion chamber, the tendency to detonate limits the allowable temperature of the mixture. When hot air is supplied to the intake of the carbureter this may be removed. This change from preheating the intake air to heating the fuel charge should have no deleterious results, and has often shown a marked decrease in the tendency to detonate and an increase in power.

The design of the engine can reduce detonation to minimum in a given fuel by proper attention to these details:

(1) Turbulence which is promoted by the proper gas velocity past the intake valves
(2) Keeping all parts of the combustion chamber from exceeding certain maximum temperatures
(3) Location of the spark-plug
(4) Shape of combustion chamber
(5) Preventing the crest of the original explosion wave from impinging on a flat surface which itself can echo back to another flat parallel surface
(6) The distance of the spark-plug from the nearest opposite surface

Elements of design that tend to maintain actual compression in service are

(1) Good piston and ring design
(2) Proper lubrication of cylinder, piston and ring surfaces
(3) Prevention of the warping of the valves due to uneven heating and rotation
(4) Prevention of the warping of the cylinders due to casting design and proper water distribution

It has been demonstrated that little power is available from a quiescent mixture. It is absolutely necessary for economy and power that the mixture be as turbulent as possible to promote flame propagation. This is effected primarily by the velocity of mixture past the intake valve which should be between 130 and 165 ft. per sec. Turbulence is improved by certain shapes of combustion chamber, generally such shapes are simple in contour and with few projections to dampen out the turbulence.

Engine timing and its effect on the mixture and its uniform distribution are closely related in economy to the shape of the intake passages. There is a definite relationship between gas velocity by the carbureter, the intake header and branches and valves which gives maximum power and economy.

The engineer must keep in mind that timing and gas passages can be controlled so as to promote a higher relative economy at one-quarter, one-half and three-quarter load than is usually found in the average engine.

The high specific economy which can be attained by hot intake passages and combustion chamber is one factor which suggests serious consideration. High temperature of cylinder walls is desirable, if there is no local overheating. For economy the highest water temperature is advisable without boiling.

Great loss in mileage is common due to high friction losses in the engine, particularly at the piston surfaces which in most engines account for over 50 per cent of the friction-horsepower loss.

Almost without exception the relative economies at the low loads commonly found in service can be decidedly improved by reducing the unnecessary piston friction losses.

Results

When new designs of manifolds constructed according to the foregoing recommendations have been applied to engines, it will be possible to readjust the carbureter so as to give a leaner mixture with a consequent saving in fuel as well as a more satisfactory general operation.

Results to be attained by following the foregoing methods of vaporization are:

(1) A better combustion with consequent decrease in fuel consumption
(2) A decrease in crankcase dilution by limiting the passage of unburned fuel past the pistons
(3) Reduction of carbon deposit
(4) Maintenance of the engine in such a condition as to deliver higher power over longer periods between overhauls
(5) Improvement of the general performance of the engine as to sweet running and ability to accelerate smoothly and rapidly

The committee notes a strong tendency at present toward making high volumetric efficiency secondary in importance to securing the best average performance with respect to power, economy, low maintenance cost and long service between cleaning the combustion chamber and spark-plugs. The most rational design is that which favors a high torque and economy at speeds and loads usually found in service rather than a sacrifice of average performance for some special result desired only by a few or seldom demanded by the average user.

Committee

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R. J. Broege F. C. Mock
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Assisted by

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SLIPSTREAM CORRECTIONS IN PERFORMANCE COMPUTATIONS

REPORT No. 71 of the National Advisory Committee for Aeronautics, Washington, is concerned with the variation of the slipstream velocity with the rate of advance of a propeller, and treats the subject from both the experimental and the analytical standpoints. The experimental portion is based on Eiffel's work. The relative increase in the slipstream velocity is much less rapid than that in air-speed, and the slipstream correction therefore falls off as the air-speed increases. A method, based on the momentum theory of propulsion, is given for determining the slipstream correction for any given propeller under any conditions. The curve of slipstream velocities thus determined by theory checks within 2 per cent of the experimental curve for the one propeller for which data are available.

Flexible Shaft-Joint Progress

By Carl A. Schell[1] (*Member*) Cleveland Section Paper

A GREATER tendency than ever before toward light weight and the elimination of as much owner service as is practicable, has been evidenced in the cars brought out in the past year. The main reasons for reducing weight are the high cost of all chassis materials and the ever-rising cost of fuel and tires; the diminishing of owner service is desirable because the average American has less time to devote to the care of his car.

Much service can be eliminated by reducing the number of chassis parts that require lubrication, in particular those that always have been difficult to lubricate. Possibly the hardest part to lubricate on the present-day chassis is the universal-joint. To do this a man must change his whole attire and lie under the car. The objection to greasing universal-joints to keep them quiet has become so pronounced that many large manufacturers of passenger cars have adopted the flexible-fabric type of propeller-shaft joint. Others are now using it as a coupling between the engine and the transmission. Several manufacturers are using fabric joints on the propeller-shaft of 1 to 6-ton trucks. Many additional firms are using this type of joint between the engine and the gearbox. The total number is about 250 per cent greater than in 1918 and 450 per cent more than in 1917. The recent trend of design has been such that it is becoming possible to install an increasing number of fabric joints on the different cars. This is because designers are laying out the chassis with straighter propeller-shafts, and a majority have adopted semi-elliptic springs at the rear. These springs are being designed very flat, which tends to cut down the lateral axle movement between the transmission and the rear-wheel center-line. Most chassis are now being laid out with a propeller-shaft angle of between 2 and 3 deg., with a maximum of about 9 deg. and a total lateral axle movement averaging about ⅝ in. This makes an ideal condition for flexible-fabric joints. If the chassis has been laid out along these lines, the next problem is what disk combination will be best. The four main factors to be considered are (*a*) the amount of torque to transmit, (*b*) the maximum speed at which the shaft will operate, (*c*) angularity and (*d*) lateral movement.

Practically the only way to find the proper disk combinations was by a long series of road tests to determine what combination gave the longest service, caused the least amount of thrust on the transmission and axle parts and ran the truest. A large number of disks of small diameter and large total thickness will keep the shaft centered very well but will be rather severe on the adjoining parts unless the angle and the lateral movement are very small. An assembly large in diameter and of small total thickness is ideal as far as thrust and angularity go, but has not enough fabric to keep the shafts centered truly. For example, with a four-cylinder chassis weighing 2800 lb., having an engine developing 30 lb.-ft. of torque, a minimum shaft angle of about 3 deg. and an axle movement of about ⅝ in., we have found that the ideal disk combination is composed of three 5/16 by 7-in. disks, having a 5¼-in. bolt circle, with a center hole approximately 2¾ in. in diameter. In connection with this we use a washer 1 5/16 in. in diameter. This joint is required to transmit 1560 lb.-in. on high gear and about 4600 lb.-in. on low. This will stress the disk about 550 lb. per sq. in. maximum and about 180 lb. per sq. in. when the car is running in high gear, providing that the engine develops the full torque. With a fabric of a tensile strength of 2700 lb. per sq. in., it is evident that an ample safety factor is allowed. Stressing a fabric of this strength to the figures stated has been found to give ideal service, a large number of shafts having run over 50,000 miles each under similar conditions. With this combination there is enough flexibility to allow for the lateral movement and for angularity and enough fabric to keep the shaft well centered. A thicker and smaller disk would transmit the torque as well, but it would throw too great a load on the adjoining parts, as it takes a proportionately greater load to flex them, and a larger thinner assembly would allow the shaft to wobble.

Recommended Practice

Good practice for the average chassis of today is to make the total disk thickness about one-eighth of the diameter and the center hole of the disk about 40 per cent of the total diameter. If the center hole is too large it will allow the assembly to whip, as there will not be enough fabric in the center to hold the rotating member in its proper position. It was also found that when the shafts run at very high speeds it is advantageous to make the floating member as light as possible, as any tendency to whip is in proportion to the weight of this member. A light center member can be obtained by using a heat-treated nickel-steel tubing. It is also necessary to balance the entire assembly accurately to get a smooth-running shaft. This lightness is a precaution that must be taken with fabric joints, due to the fact that the floating member is held in position by the disks alone. Several firms have tried centering devices to accomplish this, but these require lubrication and eliminate some of the benefits derived from the fabric construction. These joints have been working successfully on some of the fastest-running shafts in this country, and centering devices were found unnecessary where the details already mentioned were incorporated in the design.

In addition to the light floating members, a good type of washer should be used; one that will grip the fabric thoroughly without cutting it and that will have a comparatively smooth or rounded edge so that, when the disks flex from side to side, the edge of the washer will not cut into the fabric. The correct length of the propeller-shaft should be determined very accurately, so that the compression and tension on the disks will be balanced. If the shaft is very much too long or too short, bearing and disk troubles will result. This accuracy is needed because practically all the fabric joints being used

[1]Chief engineer, Thermoid Rubber Co., Trenton, N. J.

are without splines; the axle movement is taken up by the flexible disks.

In making up the disks a very good grade of fabric should be used, preferably that made of Sea Island cotton, or a mixture of this cotton with a good grade of American fabric. We have found through a long series of road tests that the disks stay in better shape and hold the shaft more accurately if the six or eight plies of fabric are staggered or assembled fan-wise, so that all centrifugal or torsional stresses are overcome evenly in all three driving sectors of the disk. The three-arm type of fabric universal-joint is universally used, because this has been found to be the most practicable for the flexibility required. If a two-arm spider is used, there is too large a distance between bolt-holes; the fabric will stretch excessively unless made exceptionally heavy, and it will have 50 per cent less driving capacity. Cotton fabric is generally woven in two directions, the threads comprising the warp and the filler. In this case, with a three-arm driving spider and the weave of the cotton run in two directions, it is advantageous to stagger the threads to balance the stress on the entire disk. With the staggered type of disk, no matter in what position the bolt-holes are punched, the staggering will cause the floating sections of the disk held alternately by the stationary sections to run more uniformly. On the torsional load, with the staggered construction it is impossible to take a greater load on any one sector, because all sectors have the same amount of stretch and flexure. With the disk assembled in the straight fashion, it is possible to take a greater part of the load on a section with the holes punched in certain positions so that the pull will be directly with the fabric; on the other two sectors the load will be pulling on the bias where the stretch is always greatest.

In reference to saving weight, the average flexible joint is 28 per cent lighter than metal joints of the same capacity, a saving of 8 to 14 lb. on the average car. It is unfortunate that the price of good fabrics is so extremely high. This makes the disk a rather expensive item. Adding the disk cost to the cost of high-grade metal parts, makes the entire propeller-shaft higher at present than with a metal joint. Not only does the fabric joint do away with the necessity of lubrication, but it also acts as a shock-reducer and sound insulator and it is absolutely quiet in itself. The users of this type of joint have found that the entire chassis, particularly the axles, will withstand considerably more stress when the car is so equipped. It also eliminates the conducting of axle noises up through the frame to the vicinity of the driver's seat.

The Discussion

A MEMBER:—What is the relative cost?

MR. SCHELL:—The cost is about 10 per cent higher than that of a good metal joint, at the present price of the cotton fabric.

A MEMBER:—You recommend using Sea Island cotton or a combination of American and Sea Island cotton. It is all American cotton, is it not?

MR. SCHELL:—It is known as Sea Island cotton to the trade. We use a cotton grown in the South. The Sea Island cotton in Arizona was started from Sea Island seed but not raised in the Sea Islands.

A MEMBER:—Is it a duck or is thread woven into a fabric?

MR. SCHELL:—It is a 17½-oz. duck. By staggering the fabric I mean that the fabric is woven in two directions. It is twisted and staggered to balance the stresses on the disks.

A MEMBER:—Is there any rust wear in the holes to cause lost motion?

MR. SCHELL:—No; there is nothing to rust.

A MEMBER:—You have two different types of washer; which do you prefer?

MR. SCHELL:—Any washer will do as long as it bites into the fabric and does not cut it; it will not loosen.

A MEMBER:—Would the annular type cut less?

MR. SCHELL:—Both worked out very well; there is no cutting with either type.

A MEMBER:—What is the comparative life of the joints?

MR. SCHELL:—That is hard to say. Metal joints not lubricated may be objectionable within a very short time. The fabric joint cannot be noisy. If anything goes wrong with the fabric it will break.

A MEMBER:—What is the average maximum thickness of the disks?

MR. SCHELL:—We always use two or three disks on a propeller-shaft. We use three disks and six washers but never go beyond three disks. The number, thickness and diameter depend upon the speed.

A MEMBER:—Have you tried any material other than cotton?

MR. SCHELL:—We have experimented with jute and material of that nature, but found nothing that will stand up like cotton. Jute is a cordage material; a good grade of rope is made of jute hemp.

A MEMBER:—How does your product differ from that of other firms?

MR. SCHELL:—They are using the straight method of assembling the disks instead of staggering them. We construct them in the way cord tires are built.

A MEMBER:—Have you tried the fabric joint under conditions where it is subjected to oil?

MR. SCHELL:—We have used it on cars on which the axle leaked oil. The oil runs out and shoots off.

A MEMBER:—Are these joints used in magneto shaft-couplings?

MR. SCHELL:—Yes; many are used.

A MEMBER:—Will this joint work satisfactorily with a torque arm?

MR. SCHELL:—Yes, where the drive is through the springs. We are supplying many cars using the Hotchkiss drive, on which the angularity is not greater than 10 deg.

A MEMBER:—Do you have trouble with clearance?

MR. SCHELL:—Yes, in some cases such as with the heel-board of the rear seat; we must allow for that. Shifting levers also interfere on a large number of cars. Attention must be paid to the building up of the disks. We give them several treatments such as pre-stretching, shrinking and chemical treatments to eliminate rotting.

A MEMBER:—Is the strength of the fiber the same in each direction?

MR. SCHELL:—Yes; in ordinary cotton there are variations in the strength of the warp and filler and also on the bias, but an inch of material can be cut out of the disk mentioned in any direction, on the side or through the middle, and an even tensile strength be retained.

A MEMBER:—What is the tensile strength?

MR. SCHELL:—It is about 2700 lb. per sq. in.

A MEMBER:—How many layers are in these plies?

MR. SCHELL:—On a ¼-in. disk, five plies; on a 5/16-in., eight plies of 17-oz. duck.

A MEMBER:—Are the fittings ever rust-proofed?

MR. SCHELL:—There is no metal-to-metal contact. The steel washer is against the disk and protected from the weather. We have not found it necessary to rust-proof any part. We paint the propeller-shaft; it does not rust any more than does the frame or any other members which are exposed.

A MEMBER:—In the weave of the fabric, are the threads equal?

MR. SCHELL:—Yes, for the warp and for the filler.

A MEMBER:—Does your firm assemble the flanges?

MR. SCHELL:—No; that is done at the various plants.

A MEMBER:—Do you find that the bolts are drawn too tight?

MR. SCHELL:—No; they cannot be drawn too tight with an 8-in. wrench.

A MEMBER:—Are the disks used where it is very hot?

MR. SCHELL:—No. Some firms are using them inside an enclosed clutch which gets warm, but there is no trouble under such conditions. One company installed a coupling very close to the clutch driving-hub. The clutch was too small and there was slipping trouble. The disk was up against the spider and the slipping generated so much heat that the disk failed. This trouble was eliminated by building a larger clutch.

A MEMBER:—Have any tests been made with a 5-deg. angle on a motor-generator set?

MR. SCHELL:—With a 5-deg. angle the power losses of a motor-generator set are almost negligible.

A MEMBER:—When three rings are used, how is the middle ring held?

MR. SCHELL:—A long bolt is run through the entire assembly. There is practically no space between the disks.

A MEMBER:—Where the disks have been installed between the clutch and the transmission, has any difficulty been experienced in shifting gears?

MR. SCHELL:—No; they eliminate much of the weight and produce an easier-shifting transmission.

SOME SUPERCHARGER PROBLEMS

A SERIES of tests conducted by the engineering division of the Air Service disclosed problem after problem in connection with the supercharger which had to be overcome before further tests could be made. Some of these difficulties were (*a*) obtaining a means of keeping the air and gas mixture ratio of the carbureter constant throughout a wide range of altitudes, (*b*) the difficulty of delivering fuel to the carbureter against a varying pressure, (*c*) the difficulty of cooling at great altitudes and the rising boiling point of water, and (*d*) the problem of providing a drain-valve to let the water out of the radiator at great altitudes in case the engine stopped, so that the engine cooling system would not be ruined by the water freezing; at the same time it was necessary for this valve to be arranged so that it would not freeze, thus making it impossible to operate it.

A special instrument had to be developed to show the pilot how to handle the exhaust by-pass-gates; in other words, to control the supercharger pressure in the carbureter without the need of making any calculations. Considerable trouble was encountered from preignition when running with a supercharger, due to the fact that air delivered to the carbureter is at very high temperature. Future designs will overcome this trouble. The fuel-feed system prior to Major Schroeder's record flight operated very satisfactorily, but in spite of this it was necessary for him to close the vents in the gasoline tanks and pump pressure in them with a hand air-pump to help the fuel-pumps deliver fuel at great altitudes. A specially prepared fuel proved to be of great assistance, as it caused the engine to run much more smoothly than was the case with ordinary fuel.

It is an interesting fact that the instrument which shows the pilot what pressure is being delivered to the carbureter recorded a pressure close to that of sea level even when Major Schroeder was at the highest point of the flight. The functioning of the supercharger was excellent throughout the flight, and the apparatus was found to be in good condition afterward.

In military work an automatic oxygen feed apparatus is used which regulates the amount of oxygen in proportion to the altitude so that the pilot need not think of making any adjustments. Major Schroeder had been in the habit of using a simple rubber tube from the neck of the oxygen flask to his mask in such a manner that he could adjust the flow by hand, as he has often had trouble in the oxygen freezing and stopping at high altitudes. On his record flight he knew that he would be up for a long time and desired to use the automatic apparatus as long as possible and believed it would work until he reached an altitude of 29,000 ft. He, therefore, took one bottle of oxygen connected through the automatic oxygen feed and one connected direct. He found, however, that the automatic apparatus did not work at all, and it became necessary for him to start using his emergency bottle at about 18,000 ft. He realized that it might run short, but thought it would last long enough for him to accomplish his record. It was probably the large amount of exhaust gas Major Schroeder was breathing which caused him to use an excess amount of oxygen. This, of course, resulted in his reaching the end of his supply sooner than he expected.

At the top of his climb he actually reached warmer temperature. The coldest temperature recorded was —67 deg. fahr. It was determined that the trade winds at this altitude blew from west to east, with a velocity of 175 m.p.h. These winds existed above 20,000 ft., and their velocity increased with the altitude.—Air Service News Letter.

BRITISH AERIAL EVENTS IN 1920

NUMEROUS and important aerial events are scheduled for the current year. Among these are a flight from Great Britain to India and back with a cargo of 1200 lb. for which a prize of £10,000 ($48,667) is offered and a series of sporting events under the auspices of the Royal Aero Club for which £2,000 ($9,733) has been set aside for prizes. Another event arranged by this club was an aerial derby race around London on July 24. In August a race is scheduled from London to Manchester and return.

Other announced events include the Air Ministry Competition for large and small airplanes and seaplanes. The first of these, for the small airplanes, was held at Martlesham Heath, June 1. The seaplane test, it is expected, will take place at Felixstowe, on Aug. 1, and the large airplane test will be held on Sept. 1. The place at which this series of trials will take place has not been definitely announced up to the present time.

From July 9 to 20 an aeronautical exhibition organized by the Society of British Aircraft Constructors will be held at the Olympia in London.

The Royal Aero Club has entered three competitors on behalf of Great Britain for the Gordon Bennett Aviation Cup Race which will be held in France from Sept. 27 to Oct. 2 and the Jacques-Schneider International Seaplane Race which will be held in Italy some time in August.—Commerce Reports.

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Shop Production-Control and Accounting Systems

By A. G. DREFS[1] (*Non-Member*)

SEMI-ANNUAL MEETING PAPER *Illustrated with* DIAGRAMS

WE are in the midst of an unusual period. Today, conditions are extremely abnormal and complex. Labor, while fully employed at the highest wages ever known, is restless and discontented. The raw material markets are uncertain, both as to deliveries and prices. Financial problems are acute. Money is commanding unheard-of rates at a time when heavy and costly inventories must be carried to assure volume. All of these factors tend to make the job of management far more difficult than ever before.

In the automotive industries there are four major divisions of activity, manufacturing, financing, engineering and sales. The first three and especially the first two are today real problems. Fortunately, there have been no real sales obstacles. It is because of that condition that most automotive manufacturers have made greater profits than ever before, even after paying unusually heavy taxes and in spite of inefficient operation. Some day the sales resistance will become greater. Business will again get to a competitive basis when success will depend on the ability to produce and sell at competitive prices.

You are chiefly concerned with the mastering of the problems of today and not of tomorrow. It is, however, vital that the solutions evolved be flexible and applicable with slight modification to the problems that arise in the future. In this paper we are privileged to discuss production control, especially the routing of materials, and systems of accounting pertaining to shop production. The two are closely related, intertwined. They cannot be separated without destroying the effectiveness and efficiency of one or both.

There is no universal production or accounting system. Your business cannot be bent or changed to meet the requirements of a system. Each business has an individuality of its own. No two companies are exactly alike even though producing identical things. Organizations function differently; their buildings, equipment, tools, etc., vary; their financial positions are unlike. All of these factors go to make individuality. The most effective system therefore is one designed to meet the specific requirements of each individual plant. This paper does not deal with a system. It deals only with advanced principles of production control and factory accounting, which, if applied skilfully to business, will tend to make management easier, more effective and more profitable.

No production control or factory cost system is modern unless it provides you with the facts before they happen. Unfortunately, most of the systems do not do this and hence are historical records only. You need to know in June what your shortages will be in July and August. By the same token you need to know in June what your costs will be in July and August. Then, if your organization is "live" and efficient the actual shortages in July and August will be less serious, because you have anticipated and overcome them. Neither will your profits be disappointingly low in July and August. You acted effectively in June to correct those conditions that might lessen them.

DIVISIONS OF THE PRODUCTION DEPARTMENT

Today, there should be two divisions in your production department, namely, "external" and "internal." The word "external" is used to designate that phase of the work required to get the raw materials into your plant before they are needed. The "external" branch of the production department must be closely related to the purchasing department. It must inform the purchasing department at the earliest possible moment, the quantities, kind and deliveries of every article needed. Further, it must follow up most assiduously the purchasing department activities. Generally, the field follow-up should be under the control of the purchasing department but the direction of the "field follow-up" should be based on the shortage reports emanating from the "external" branch of the production department. In case of anticipated acute shortages, the engineering department should, at the solicitation of the "external branch" of the production department, pass on the use of other grades of materials. Likewise, the relationship of the "external" branch of the production department should be so close to the purchasing department that they function together in the development of new sources of supply and in the rendering of aid to old sources.

The "internal" branch of the production department controls the routing, issuance, scheduling and movement of all orders through the manufacturing processes. Its problem is to complete each order before it is required and to schedule the work through the many processes so as to utilize existing equipment as efficiently as possible. Further, that equipment should be used which will produce the completed article at the minimum cost.

To secure results the production department, internal and external, must have proper "tools." Certain basic data are required. But it is not enough that the data be at hand. You can have in your shop an absolutely new lathe. The lathe as a lathe is of no production value. It needs an operator. It needs power and it needs lubricant. And so it is with your production department. After all of the necessary data have been secured it needs motive power. The "tool" requirements are therefore separate and distinct from the "functioning" requirements, especially the efficient functioning requirements.

Before attempting to control operations adequately, the production department needs the following basic data:

(1) A copy of the customer's order in case the product is not absolutely standard; if the product is standard, a periodic release from the manager's office

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(2) A correct Bill of Material for each order released
(3) A list of operations in sequence on each part, subassembly and complete assembly necessary to produce the article ordered
(4) The set-up and performance time of each operation
(5) The numbers of the machines, equipment and tools required for the performance of each operation
(6) The economical manufacturing units, pieces, for each part to be produced. These data are not required in job shops where quantities ordered are very small and where each order is different
(7) Perpetual inventory and scheduling records designed to meet the needs of the case

Given the above data, a production department can operate, but the efficiency and value of its operation depend on the development of the following factors:

(1) Efficient personnel clothed with authority and capable of securing absolute cooperation
(2) The absolute reliability of the basic data, properly tabulated and recorded, and the establishment of methods to perpetuate their accuracy
(3) Maintenance of buildings, machinery, tools and equipment at point of highest operating efficiency
(4) Efficient movement of materials from operation to operation
(5) Wage incentive to stimulate the activity of workmen
(6) Efficient inspection at predetermined points
(7) Sequential arrangement of machinery; convenient stockrooms, etc.

The Planning Department

The operating detail of a planning department obviously depends on the character of the work going through the plant. If you are manufacturing a standard product in sufficient quantities to utilize "one-purpose" machines the task is immeasurably easier than when the product is diversified or the order units are small. In the first instance, it is only necessary to balance the equipment to make periodically a given production and then to "feed" to the balanced equipment standard-size lots sufficient to produce the units of output desired. On the other hand, when the order units are small or the products diversified so that each machine must be utilized for the performance of operations on several parts, the planning problem is much more complex. Great care and ingenuity must be exercised to control the order releases so that the work flowing through the shop is balanced to the productive capacity of the equipment; in other words, in the first case the equipment is balanced for the performance of a given periodic output. In the second case the flow of orders is balanced to the shop to utilize the machine equipment most fully. It is of course true that in the second instance the equipment must be in fair balance. But the balance is much more difficult to maintain and because it is not maintained most shops are cluttered with parts which move very slowly to the final inspection.

When a well-organized planning department operates, the amount of "work in process" consists only of "live" orders which flow smoothly from operation to operation and do not congregate before a particular machine or group of machines for several days. The question necessarily arises as to how that desired end can be obtained and maintained. It is through the control of the order releases and through the organized movement of the order through the shop. This involves the utilization of the basic data previously enumerated and the intelligent exercise of the functioning requirements likewise listed, all dominated and controlled by a strong, centralized planning department.

It is absolutely necessary to centralize the planning or production department, for it is impossible for foremen and other shop executives to see more than the one department they supervise. They cannot grasp the relationship of one order to another and hence when left to their own initiative usually chase the job nearest at hand. When an order has been released to the production department, the first consideration is whether it has precedence, for reasons other than production, over some previously released order. Assuming that it does not have and that it will be scheduled in the order of its receipt, it is first necessary to schedule the order as an order without relation to any previously scheduled order. This is necessary to determine the parts on that specific order which must be processed first. For example, in the manufacture of an engine, axle or transmission, certain parts should be started before others because it takes longer to produce them or because they are required for some subassembly which of necessity must be completed in time for the final assembly. Much of this work can be standardized and previously collected data utilized, thereby preventing duplication of effort and unnecessary delays.

Scheduling an Order for Production

Knowing the sequence for the manufacture of parts for each order, it is then necessary to add this schedule to the previously accumulated ones. This should be done by machines or machine groups. It is a very easy task. Machine or machine-burden cards are operated which show at all times the jobs ahead of each machine or machine group expressed in terms of hours. Periodically these changing machine-burden records are charted and the exact status of the work ahead of each machine or machine group is shown graphically. A study of these graphs will show immediately the equipment surplus or shortage in the factory. The upper portion of Fig. 1 shows the machine burden as of a given date. Certain machines are greatly overloaded. But for the fact that the new week's schedule is very light, overtime work or additional equipment would have to be resorted to. The lower portion, graphed a week later, shows the same department. Conditions have radically changed. Instead of considering overtime work or additional equipment, the need for new orders is very apparent. Fig. 2 analyzes the causes of idle equipment and likewise the ratio of actual to standard production. Many managers are guided in their sales policy by these periodic graphs. Likewise the need for the purchase of additional equipment or the sale of surplus equipment can be positively determined.

No production system can be a cure-all for present-day manufacturing difficulties. But a scientifically designed and efficiently operated production system can and will increase output, reduce the cost of manufacture, eliminate confusion and make promises to customers far more reliable. Proper planning simply means "thinking ahead." But the thinking ahead must be based on up-to-date, accurate data, properly tabulated and skilfully applied. The farther you can look ahead and anticipate your difficulties the less your actual difficulties will be. Devise your planning system so as to permit looking well into the future.

Preparing Cost Data

Most of the records and reports utilized for planning purposes should be used likewise for the preparation of costs. The production department deals with quantities and time; the cost department with the value of each of

these factors. The complete cost of any article consists of five elements:

(1) Direct material
(2) Direct or productive labor
(3) Manufacturing expense
(4) Administrative expense
(5) Selling expense

In this paper the discussion will be confined to "Factory Costs" which includes only the first three elements and a share of the fourth which will equally measure the use of the administrative costs by the factory. Direct materials consist of all items that become a component and tangible part of the finished product. Material costs include the original purchase price of the article plus inward freight and handling charges. Where the article is small, as in the case of screws, washers, cotter-pins, etc., the freight and handling charge per piece is so infinitesimal that red tape is eliminated by classing the freight and handling charges on such items as manufacturing expense, although technically they are part of the material cost.

Direct or productive labor is that labor which is performed directly on a part, subassembly or assembly.

Manufacturing expense is that element of cost which cannot be allocated directly to a part, subassembly or assembly. Its absorption must be effected by showing its relationship to some specific or known factor. The principal items that constitute manufacturing expense are

(1) Indirect or non-productive labor consisting of that employed in supervision, maintenance, movement of materials, etc.
(2) Indirect materials or supplies, which include items like brooms, lubricating oil, cutting compounds, small tools such as files, taps, drills, hammers, etc.
(3) Direct materials used as expense as when bar steel purchased for production purposes is used for the repair of mechanical equipment
(4) Depreciation
(5) Taxes, other than those based on profits or sales
(6) Insurance, fire, liability, etc.
(7) Heat, light and power

Now, in the compilation of costs, two things must always be kept in mind, namely, that the costs are inclusive and that the distributions are fairly made. To assure costs being inclusive, each of the three major elements, materials, productive labor and manufacturing expense, should be controlled by the general books. The factory costs should be made to prove to these controls. It is in the accurate distribution of material, productive labor and especially manufacturing expense that most of the errors of cost systems are found. The tendency should be to make as many direct charges as possible and to reduce to a minimum general or miscellaneous charges.

Let us consider briefly the application of the cost principles enumerated and at the same time illustrate the connection of the cost and production records. As in the case of the production department, the cost department is concerned with the bill of material; with the lot order units; with a list of operations on each part and with the machines, equipment and tools required to perform the operations. The cost department utilizes the bill of material to assure itself that the cost has been secured on every part. Further, the bill of material provides such data as parts names and numbers, material specifications, pieces per unit, etc. These data must be augmented by the weight of those parts purchased by weight; for example, gray iron, malleable or steel castings; and the size for items purchased per foot as instanced by tubing, wiring, etc.

While the production department controls the issuance of materials to the shop and as a result operates the perpetual inventory records, the cost department is vitally concerned with a copy of all material and supply requisitions, accurately made out and priced. There is no advantage in operating two sets of stock records. One set correctly maintained is sufficient.

The method of collecting labor costs depends entirely on the nature of the product. In some instances, as in the case of job shops, an "order" labor cost is sufficient. Generally, more detailed labor costs should be collected,

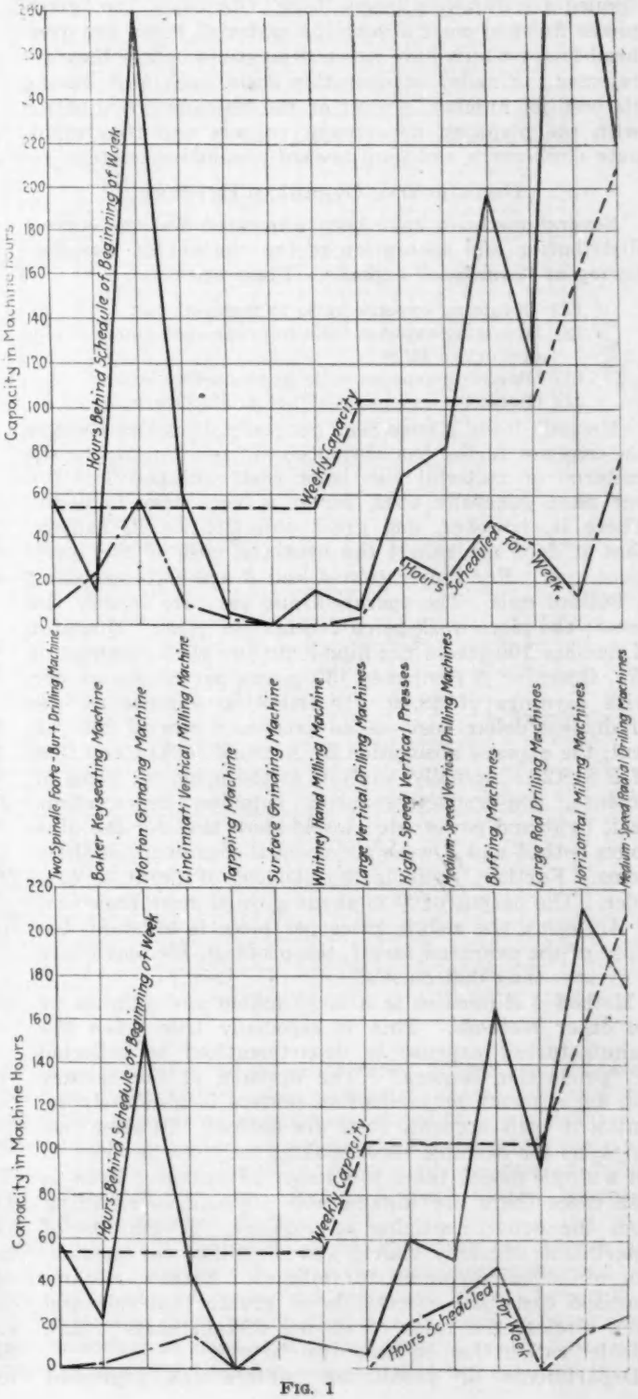

FIG. 1

for these provide the means of checking the shop labor efficiency. The most satisfactory labor cost therefore is secured when the tabulation is made by parts and operations on such parts. It is, however, absolutely essential that when part operation costs are secured, these tabulations be tied up with the production department lot records. Today, there are many instances in which extra operations are needed or the piece rates are temporarily suspended necessitating lot control. In this manner the inclusion of extra labor costs is positively assured, whereas without that control the "extras" are frequently forgotten.

There is an added reason for lot control. The pieces spoiled are usually a heavy item. Obviously, the "good" pieces finished must absorb the material, labor and overhead losses which have accrued on parts before they are rejected. Finally, lot operation costs, each part having its own lot number, permit of the absolute coordination with the planning department records and thus eliminate duplication and tend toward absolute accuracy.

Distributing Overhead Expense

Several methods have been advocated for the correct distribution and absorption of the element of manufacturing or "overhead" expense. These are

(1) Obtaining expense ratio to material cost
(2) Obtaining expense ratio to prime cost, material plus productive labor
(3) Obtaining expense ratio to productive labor
(4) Obtaining expense cost per productive hour

Methods 1 and 2 have been generally discarded because the expense factor has absolutely no relationship to the material or material plus labor cost. Method 3 is the one most generally used, for it is very easy to apply. There is, however, one great objection to it, namely, that it does not reflect the overhead cost of the inefficient man. For illustration *A* and *B* are both operating a Bullard mill. The operation and part are exactly the same; the piece-work price 7 cents per piece. Operator *A* finishes 100 pieces per nine-hour day with earnings of $7. Operator *B* completes 130 pieces per nine-hour day with earnings of $9.10. Distributing expense on the productive dollar basis at an arbitrary rate of 200 per cent, the expense absorption by *A* would be $14 and that of *B* $18.20. Actually, analysis of the principal items of expense, non-productive labor, supplies, depreciation, heat, light and power, etc., would show that for the nine hours both *A* and *B* were about equal consumers of these items. Further, there is the element of profit to consider. The output of *B* is about a third more than that of *A*. Since the selling price per piece is constant, because of the overhead factor, the profit on *B*'s operations is greater than that on *A*'s.

Method 4 eliminates to a large extent the fallacies of the other methods. This is especially true when the manufacturing expense is departmentized or collected by "production centers." The division of the factory into departments or production centers is absolutely essential if truly accurate costs are desired. In some factories, as for example those making only one product in but a single model, there is a lesser advantage. Even in such cases there are innumerable advantages resulting from the departmentizing of expense. It permits of department efficiency charts and simplifies the application of bonus payments to foremen. Finally, departmentized costs are susceptible of greater analysis and often disclose the value of having certain parts "made outside" rather than in one's own factory.

Departments or production centers can represent either a unit of operation, as instanced by a milling machine department, or a unit of product such as a knuckle department in a factory producing front axles. To each department or production center there should be charged the actual cost of all of the items of manufacturing expense. Thus, non-productive labor directly employed by a department, should be charged to it; supplies should be requisitioned and charged to the department consuming them; depreciation should be levied departmentally, the same being based on the value of the floor-space, machinery, equipment and tools employed in each department. In a like manner the other items of manufacturing expense should be analyzed and departmentally distributed.

No separate mention has been made of the so-called "machine-hour" method of overhead distribution. After the factory has been divided into departments or production centers, it is often found that the machine-hour method is extremely desirable for some departments. Automatic screw machine departments, where one operator runs several machines, offer an excellent illustration. In such cases the machine-hour, rather than the productive hour, is unquestionably superior.

Securing Complete Factory Costs

To secure a complete factory cost, the three elements, material, productive labor and manufacturing expense, are summarized. The first summary will be by parts, then by subassemblies and finally for the complete assembly. Administrative and selling expenses must be added to the factory cost before a complete cost is obtained.

In the earlier portion of this paper the statement was made that no production control or factory cost system is modern unless it reveals the facts before they happen. Proper planning does permit looking ahead. Where the planning and cost systems are coordinated it is not only possible to look ahead in terms of quantities but also in terms of dollars and cents. It is merely a case of correctly evaluating the elements of cost. In the automotive industries the material cost is usually the dominating element. This is particularly true in the case of the assemblers of cars and trucks who purchase the principal parts or units. The same condition applies to the manufacturers of axles, engines, transmissions, frames and other important parts, but in a lesser degree. It is therefore extremely important that reasonably accurate future material costs be tabulated. To compile anticipated material costs, the following elements should be brought together:

(1) Quantities and price of materials on hand and in transit
(2) Quantities and price of unfilled orders on which no alterations of prices will be made
(3) Quantities and price of unfilled orders on which alterations in prices may be made
(4) Estimate of price increases on items enumerated under (3) and the probable date price changes will become effective
(5) Factory production schedule based on production department charts and records

A combination cost-production record must be utilized. This record lists in bill-of-material order all parts with the pieces required to make one complete finished unit. On each part line there will be shown the quantities of materials on hand and in transit and the purchase cost of each. These known costs will be projected by months, using as the basis the production schedule. Thus, in the case of an engine manufacturer, let us assume that the first item was a cylinder block, and that 1400 pieces were on hand or in transit on June 1 and that each one cost

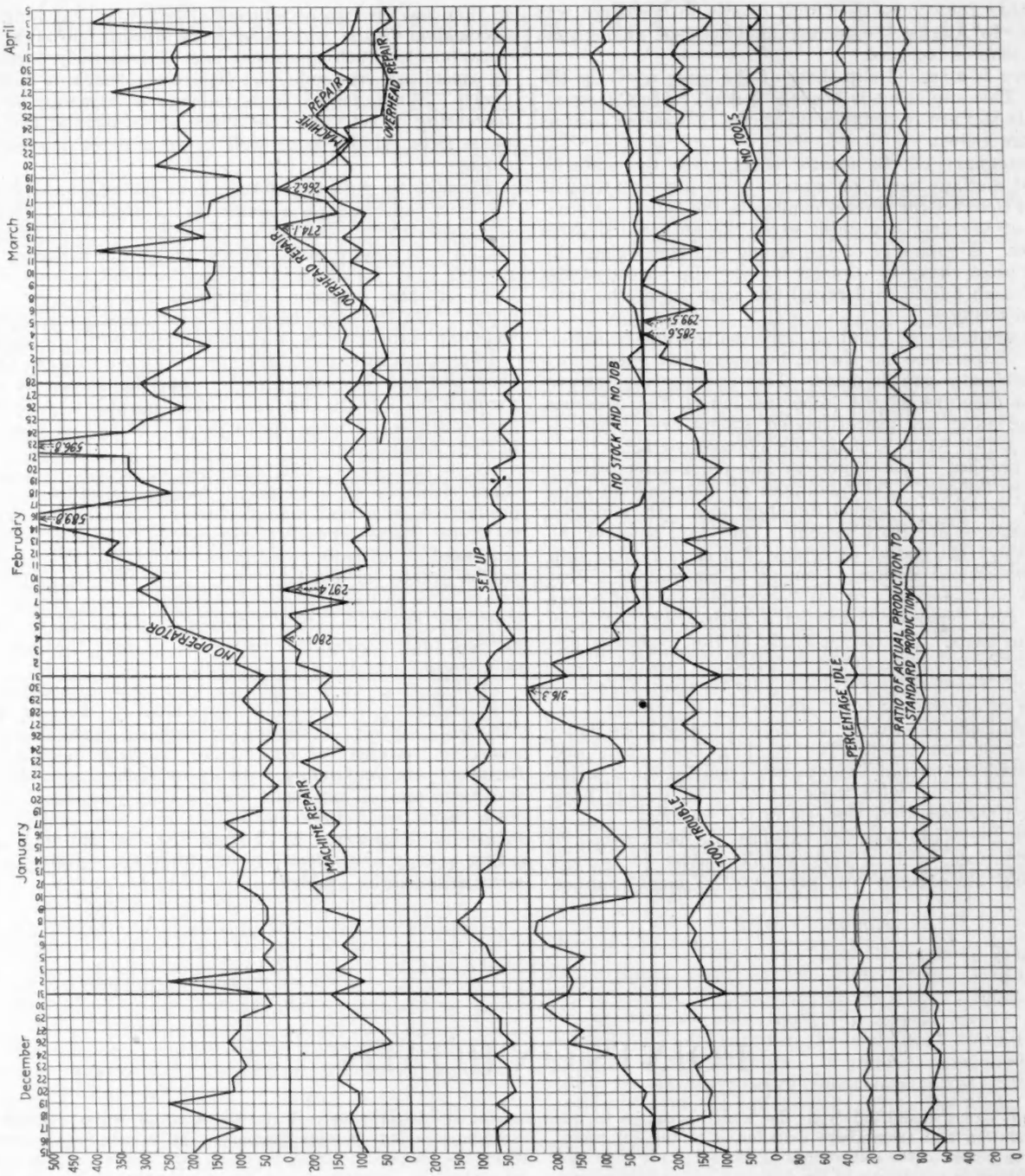

FIG. 2

$15, delivered. Let us further assume that the production schedule indicated a consumption of 800 per month; that there were 2000 pieces undelivered and that because of a recent price advance the cost of the undelivered 2000 would be $16 each. On the cylinder-block line, the price in the June column would be $15. In the July column it would be $15.25, 600 at $15 each and 200 at $16 each; in August, $16; in September, $16; and the remainder at whatever price the next purchase order specifies. Provision is made for recording the quantities and prices of additional purchases.

Farther down on the form we find, pistons, four per engine. Of these we have on hand or in transit 4000, costing delivered 90 cents each. There are undelivered on order 12,000, also contracted for at 90 cents each. The purchasing department states that on 10,000 of the 12,000 it is best to anticipate a raise of 5 cents each. This is then recorded on the piston line as follows: June, $3.60; July, $3.60; August, $3.60; September, $3.60; October, $3.60.

A short slip sheet is inserted over the master sheet which extends only over the monthly tabulations. The slip sheet is headed "Anticipated Price Changes." On this slip sheet, piston line, in July there is noted a price increase of 0.0063 cent, this being the effect per engine of the anticipated increase of 5 cents each on 400. On

the other 2800 to be used that month no allowance was made. In August, September and October, an increase of 20 cents is recorded.

There is a second slip sheet of the same width as the first. This slip sheet is headed "Actual Price Changes." On this slip are recorded actual price changes as soon as they are known.

A summary of the master sheet gives the material cost of engines based on materials on hand, in transit and on contract for several months in the future. A summary of the first slip sheet gives the anticipated price changes. A summary of the second slip sheet gives the actual price changes. Comparing the slip sheets at the end of each month, will reveal the accuracy of the anticipated changes.

It is not contended that all price changes can be anticipated. Experience has shown, however, that remarkably close estimates can be made. This is especially true in the manufacture of the important units, for, whereas some advances are overestimated, others are underestimated, which tends to make the average correct.

The problem of passenger-car and truck assemblers is far more difficult. The quantities of materials on hand and in transit are proportionately less. In addition, price changes are more violent. They can, however, be reasonably anticipated, especially if a close relationship with the several sources of supply is maintained. Productive labor costs can be very accurately foretold where all, or most, operations are on a piece-work, bonus or premium basis. A constant study of the "earnings per hour" by departments should be made. Where low earning points exist, all operations should be studied, for the purpose of increasing their efficiency. In the event no betterment can be effected, an allowance should be made on the first slip sheet. The existing labor costs and anticipated and actual changes are recorded on a series of sheets identical with those which have already been described for compiling the cost of the material.

Where the manufacturing expense has been properly departmentized, it is a very simple matter to foretell accurately the expense cost per hour. Violent changes in this cost are caused almost entirely by a lessening or increasing of the volume of work flowing through the department. Such conditions can be accurately foretold by consulting the production-department machine-burden charts. When these charts indicate a lessening or an increasing of activity, a sufficient adjustment of the expense rate can be made well in advance of the actual change.

Finally, the expense costs per hour can be standardized for each department. Manufacturing expense at standard department rates can be carried to the general ledger. In those cases where the actual expense is greater than the standard expense, a debit balance will exist on the "Unearned Manufacturing Expense Account." On the other hand, if the actual expense is less than the standard rate, a credit balance will be created.

Departmental expense rates can be stabilized so that they will not fluctuate greatly from the standards set through the introduction of a bonus, payable to foremen and other supervisors for expense reductions effected in their departments.

As in the case of the tabulation of actual costs, the three elements of anticipated factory costs, material, productive labor and manufacturing expense, are summarized. These summaries are compiled by months and are based on an anticipated production. Should the output be greater or less than anticipated, the value of the record is in no way impaired. All that is necessary is to move the entire schedule forward or backward by the amount representing the difference between the anticipated output and the actual output.

In this paper an attempt has been made to show the relationship of the planning department to the cost department and the tremendous value of such departments to managers of automotive institutions. Manufacturers are confronted with many difficulties. New and more difficult problems are constantly arising. To meet them successfully an insight into the immediate future is necessary. By having that insight and by acting quickly and effectively, many of the existing uncertainties can be avoided.

POINTS ON ROADS

As loads are transmitted from the wearing course to the foundation and from there distributed to the subgrade, the bearing power of the soil composing the subgrade is an important factor in the design of the highway. It is well known that the bearing power of soils in many instances is materially increased by efficient drainage. The roadway, therefore, should be drained so that the maximum bearing power of the subgrade is developed. While a poorly drained roadway might support a light rural traffic, it will be rapidly destroyed if subjected to commercial motor transport including, for example, several 5-ton trucks. The greatest improvement noted in American foundation practice is the use of cement-concrete foundations, or stone foundations of equivalent strength, on State trunk highway systems.

The highway transport engineer or manager can neither assume that drainage systems and foundations have been scientifically designed nor that these important elements of a highway have been constructed in accordance with practice based on service tests. Highway transport literature contains many references to cases where motor trucks have become mired in poorly drained roadways or have broken through wearing courses supported by weak foundations. When the transport survey is made, care should be taken to determine, by inquiries along the route, the ability of the roadway to carry heavy loads especially during the spring. It is well to keep constantly in mind that an ideal roadway surface is not necessarily an indication that the drainage system and foundations are suitable for motor truck traffic.

It is self-evident that bridges of trunk highways connecting municipalities should be designed for loads of not less than 30,000 lb., and it would appear advisable, considering the character of the structure, to follow the practice of the Pennsylvania State Highway Department and design highway bridges for loads of 40,000 lb. The clear width of the roadway of a bridge should comply with the requirements pertaining to roadway width. The overall height of 12 ft. 2 in. for motor trucks should receive attention. This is an important factor, not only in the design of through truss bridges but likewise in providing for clearance underneath railroad bridges.—Arthur H. Blanchard.

The Motor Transport Corps Transcontinental Convoy

By RALPH B. BURTON[1] (*Non-Member*)

ON July 7, 1919, an epoch-making run was started from Washington to San Francisco, Cal., a distance of approximately 3600 miles, under the supervision of the Motor Transport Corps, commanded by Brigadier-General Charles B. Drake. The convoy left Camp Meigs early on the morning of July 7 and proceeded to the White House, where a mile-stone was dedicated by the National Highway Association in the presence of the Secretary of War, the Chief of Staff, numerous Senators and Congressmen and ranking officers of the Army. The Secretary of War directed the convoy to proceed overland by way of the Lincoln Highway to San Francisco, where it arrived on Sept. 6, 1919. This completed the first successful convoy across the United States. The run was made to

(1) Give an extended service or performance test of the several standardized types of motorized Army equipment used for the transportation of troops and cargo, and for other special military purposes

(2) Cooperate in the good roads movement by encouraging the construction of adequate highways across the continent

(3) Demonstrate the practicability of long-distance motor, mail and commercial transportation and the necessity for the judicious expenditure of federal governmental appropriations for highways and their upkeep

(4) Collect detailed data for use in connection with the technical training of commissioned and enlisted personnel of the Motor Transport Corps in the essential functions of the Corps, operating and maintaining motor transportation

(5) Recruit personnel, especially for the Motor Transport Corps mechanical training schools

(6) Provide an opportunity for extensive studies in terrain observation by certain branches of the Army, particularly Field Artillery, Air Service and the Corps of Engineers

(7) Afford the general public an opportunity to observe or follow through publicity channels the development of military motor vehicles and apparatus in relation to the importance of their influence in winning the war

Back of the run were placed the resources of the War Department and the cooperation of the Department of the Interior. The Society of Automotive Engineers, the American Automobile Association and other automotive organizations cooperated in the successful completion of the run.

ORGANIZATION OF PERSONNEL

MILITARY

(1) Companies E and F, 433rd Motor Supply Train, approximately 220 officers and men
(2) Service Park Unit 595, approximately forty officers and men
(3) Company E, Fifth Regiment of Engineers, approximately thirty officers and men
(4) Medical Detachment, approximately fifteen officers and men
(5) Commissioned officers attached to the train as observers

CIVILIAN

(1) Observers from the War Department
(2) Observers from the Good Roads Bureau
(3) Observers from commercial manufacturers of various vehicles used

With the exception of those from the War Department the civilians were not under the jurisdiction of the Army in any way. The reason for their accompanying the convoy was to make reports tending to improve the general design of the motor apparatus and the various accessories used thereon. Officials of the Lincoln Highway Commission accompanied the convoy as pilots. They were of considerable assistance in selecting the best route and in making arrangements with the different Lincoln Highway agents for making repairs to the roads and bridges. In addition, they attended mass meetings at which good roads talks were made, asking support for a federal system of highways. Many of the drivers were newly enlisted men who had had very little military training or knowledge of motor trucks. Before the convoy was completed, however, these men were very proficient as truck drivers, due to the fact that the roads encountered, especially through the mountains of the West, required driving skill of the highest order. The Engineer Corps was responsible for the repairing of roads, reinforcing of bridges, and filling in of cuts. Camp sanitation was handled in a very efficient manner by the Medical Detachment, resulting in excellent health for the entire personnel throughout the trip.

ROAD CONDITIONS

Good roads were encountered throughout Maryland, Pennsylvania, Ohio, Indiana, and Illinois. Fortunately, the dirt roads of Iowa were in satisfactory shape, there having been no rain there for several weeks. From Council Bluffs on, however, the roads grew steadily worse except near certain cities. It became increasingly difficult to get the heavy cargo trucks through the soft muddy roads and over the bad grades. From the Rocky Mountains to San Francisco the convoy encountered fine macadam roads.

In maneuvering the heavy trucks through poor stretches of road, such as deep sand and mud, various expedients were tried. The most satisfactory was to employ a duck-board similar to that used in the trenches, but much more substantial. The duck-boards were approximately 25 ft. long. Except in extreme cases they gave sufficient support for traction, particularly in sand. Sometimes six or more trucks were chained together and sent through bad stretches, the trucks behind pushing the ones ahead and the latter in turn acting as tractors.

OPERATION AND MAINTENANCE

Practically every make of vehicle adopted as standard by the Army during the war was represented in the con-

[1]Official observer on the Motor Transport Corps Transcontinental Convoy.

voy. The vehicle roster was eight passenger cars of two different makes; six light delivery trucks of three different makes; three ambulances of one make; four 5½-ton trucks of one make; three 3-ton trucks of a commercial make; three 3-ton four-wheel-drive trucks of commercial make; twenty-two 3 to 5-ton standardized Class B trucks; and nine 1½-ton trucks of three different makes; there were also six motorcycles of two different makes. Trailers of three different commercial makes were taken on the trip. Most of the trucks were in good condition when they left Washington. Some, however, were old trucks of which no mileage record had been kept. Some of the trucks joined the convoy at Chicago, mostly new standardized Class B trucks. The cargo carried varied from day to day, but the majority of the trucks were greatly overloaded. One truck carried an overload of 40 per cent most of the way across the country.

All of the convoy except two motorcycles, one light delivery truck, one 1½-ton truck and one trailer arrived safely at San Francisco. The light delivery truck skidded and rolled down a steep bank near Pittsburgh. With the exception of the trailer, the other vehicles had mechanical troubles. The trailer was a heavy pontoon trailer used by the Engineer Corps. On account of the poor roads it was left at Omaha.

Two motorcycle riders acted as pilots, leaving camp each morning about an hour earlier than the rest of the train. They tacked small paper triangles on conspicuous posts at each turn or intersection of the road. They notified the convoy commander of any detour to be made or of any bridge repair work to be done.

Engineering Recommendations

On all long-distance trips the number of specially equipped trucks should be reduced to the lowest possible minimum. The number of different makes of truck should be reduced to not more than one for any given capacity. This does away with carrying a considerable amount of spare parts, different size tires, etc.

Much time can be gained by having a standard speed rate. At one time during the trip the vehicles were stretched out over a distance of 31 miles, due to the different speeds of the trucks. No convoy should be run having in it trucks of only one capacity. The train should be run in sections so that the smaller and faster trucks can reach the next stopping place in time to have the camp well laid out before the heavier trucks arrive. The gear ratio on trucks of the same capacity should be designed to give the same speed. Solid-tired trucks should be equipped with large single rather than dual tires, as the former give better traction and wear better. In deep sand, a ridge of sand is pressed between the halves of the dual tires, increasing the road resistance. It is recommended that in all convoys the height of all bumpers be the same both front and rear. The bumpers should be faced with steel plates. The lighting system of the trucks was very poor. The trucks were equipped with oil lamps, these being inadequate, especially in the dust encountered on the American Desert. Skid chain devices should be standardized. Practically every make of truck on the convoy was equipped with a different type of chain. It was shown beyond doubt that the skid chain device designed for use on the standardized Class B truck was most satisfactory.

Motorcycles are of little use in convoy work. Practically all of the machines had to be carried at times in the trucks, due to sandy and muddy roads. It was found that the light-weight motorcycle in some cases was able to negotiate bad roads which the heavier motorcycles could not go through. Motorcycles with sidecars having standard gage were in difficulty on most of the Western roads. An extension axle was fitted to several of these cars so that the gage was the same as the standard wagon gage. This enabled the motorcycles with sidecars to get over the roads.

A radiator of the tubular type with cast upper and lower tanks should be adopted as standard on all Army vehicles, as it is simpler to clean and repair. It also permits parts of one radiator to be used on other radiators as these parts are machined to give interchangeability. The radiators should be spring-suspended. Flat belts should be used for driving the fans and the material should be very good. It is thought that 50 per cent of the delays were caused by fan-belt trouble. The belts should be of the endless type rather than laced. V-fan belts are not desirable, but if used should be protected by some sort of dust-pan placed in front of the lower pulley. Either radiator shutters such as those on the Class B truck should be standard on all trucks or a thermostat for controlling the temperature of the water should be installed. As a rule all radiators on commercial vehicles are too small to give proper cooling in Army use.

Valve-tappet arrangements on the Class B truck engine gave serious trouble. The heat treatment of the cam rollers evidently varies according to the firm making these parts.

Miscellaneous gaskets on the engines should be done away with and copper-asbestos gaskets or gaskets of approved material used. Considerable trouble from leakage, especially in the inlet pipe, was experienced on all trucks.

It is absolutely necessary in convoy work that the governors be set to give a more efficient speed for a particular truck and that the drivers be cautioned not to disconnect the governor. It was a common occurrence to see a truck that had been pulled out alongside the road for the purpose of making minor repairs, running at a speed of from 20 to 25 m.p.h. in an effort to regain its proper place in the convoy. This practice should be discouraged as the vibration and wear-and-tear of the engine are too great.

Carbureters should have adjustments and moving parts enclosed and protected from the dust in some manner. The moving parts should be few in number and the various adjustments should be difficult to make so that the inexperienced Army driver will not attempt to change them on the road. The air-choke valves gave considerable trouble, due not only to the clamp-arm loosening, permitting the valve to close partly, but also to the shutter working loose from the shaft. A large drain-valve should be placed in the bottom of the gasoline tank in order that gasoline can be drained out for the use in trucks stranded on the road. An air-cleaner is absolutely necessary in sandy traveling. It was frequently necessary to stop to clean the thick alkali dust from the carbureter. This dust was drawn into the air-intake and soon clogged the carbureter.

The electrical systems in general gave excellent service except that in sandy sections fine dust collected on contacts, interfering with their adjustment. It is not recommended that electrical or mechanical starters be placed on trucks intended for purely military uses; provision should, however, be made so that these starters can be installed for peace-time organizations, such as public roads, Post Office Department, Interstate Commerce Commission and other departments of the Government, to which war-time vehicles are transferred. The side-lights and searchlights used on the trucks were entirely un-

suitable, it being impossible to see much more than 15 ft. ahead. The carbide generators were unsatisfactory. The present construction having clamps made to throw over center is not good, as the vibration of the truck and the weight of the tank tend to open up the clamps, permitting the tank to drop from the generator. The hose connection from the generator to the searchlight should be made of flexible metallic tubing instead of rubber tubing.

All clutches should be of one type, permitting the carrying of a considerably less number of spare parts in the repair trucks. The control levers of the transmission should be standardized. To relieve the strain under which the drivers are placed, it is necessary sometimes that they be shifted from a heavy to a light truck and vice versa. A transmission brake should not be used on the heavy trucks, but is perfectly feasible in Army work on light delivery trucks and passenger cars, although it is preferred that the regular type of braking on the rear wheels be employed to use a standardized design. It is recommended that a unit powerplant having shaft drive to the rear wheel be employed on motorcycles instead of the chain drive now employed. While this may complicate the design, a chain drive as now used seems to be impracticable, especially in sandy country under Army conditions.

The braking systems at present adopted on the standard trucks are not in general very satisfactory. The brakes on the Class B truck gave the least trouble of any on the convoy. These are properly designed, so that even though the drive be taken through the springs, there is no grabbing action or moving of the brake pedal and lever. The brakes themselves are expanding bands operating on the brake-drums mounted on the rear wheels.

The spark and throttle controls on the various trucks are exceptionally well designed with the exception of the accelerator pedal. Considerable trouble is experienced in operating this, due to its various locations and size. The Class B trucks on this convoy had a foot accelerator which was exceptionally hard to operate. This design has been changed, however, so that the push-down type of pedal, mounted between the transmission control and the brake pedal, is used. Some commercial trucks have the accelerator pedal mounted between the clutch and the brake pedals. This is very undesirable as sometimes the driver accidentally steps upon the accelerator pedal when it is his desire to throw out the clutch or operate the brakes. The steering-gears were very strongly constructed, the only criticisms being the difficulty in lubricating and that a greater gear-reduction should be used to make the steering easier.

Metal wheels should be standardized for all heavy cargo trucks. Wood wheels are not always satisfactory even on the lighter Army vehicles for military service. A considerable amount of trouble was caused on the transcontinental convoy, due to shrinkage of the wood artillery type wheels with which most of the trucks except the Class B were equipped. In one case this shrinkage permitted the tire to creep from the felloe band. In connection with the use of pneumatic tires on trucks of above 1½-ton capacity, there is a considerable divergence of opinion in the Army at the present time. The odometers used in the wheels were as a rule unsatisfactory.

The bodies as a whole were well designed and built. About the only adverse criticism advanced by observers on the trip was that the trucks of one make had wheel interference with the mounting sills. This, of course, is easily remedied by moving the cross sills to a different location, giving ample wheel-housing clearance. Non-rigid tops should be used in all cases, as clearance of viaducts, tunnels, etc., in the United States is not sufficient for the rigid tops at present in use on some Army vehicles.

Horns, body hardware, etc., should be mounted in better fashion, as at the end of the trip there was not a rope cleat or stake pocket that was not loose. Hood-fasteners should be redesigned as they are not sturdy enough to withstand rough travel. The trip across the desert proved beyond a doubt that at high temperature the efficiency of the engine is improved by having either one or both sides of the hood open. Very few vehicles, however, had provision for holding these when folded on top. The result was that they soon fell down, not only breaking the hood-fasteners but damaging the ledge on which the hood rests. Some arrangement should be made so that the sides can be easily removed or held securely so that there will be no danger of them falling when folded back to facilitate cooling of the engine.

The results of the transcontinental convoy were very gratifying to those who instigated it, as much information of military value was gathered, and the good roads movement was advanced.

Opportunity is taken at this time to thank the various observers who accompanied the convoy, for the numerous items of information concerning incidents of the trip which were incorporated in their official reports.

THE NECESSARY HORSE

AT the opening of the war the British paid $175 for cavalry horses and $210 for artillery horses. During the last two years of the war they paid $165 for cavalry horses and $190 for artillery horses. They also paid $220 for transport horses weighing from 1400 to 1500 lb. and $230 for horses weighing from 1500 to 1700 lb. The United States in its purchases paid $165 for cavalry horses, $190 for artillery horses and $230 for transport horses. These were the extreme prices paid by any government, as the French and Italian purchases were made at slightly lower figures.

The regular dealers in New York City who make a business of purchasing high-class draft horses and assembling them in pairs report that they have never had such a demand for good draft horses and that prices have never been as high as they have been during the months of March, April and May of the present year.

The reason for this is that horses and mules are still the chief source of motive power in agriculture and draying. They have been read out of existence a good many times in the world's history. Nevertheless, the United States census for 1910 revealed 19,833,000 horses and 4,210,000 mules on farms, and the estimates of the Department of Agriculture for Jan. 1, 1920, show 21,109,000 horses and 4,995,000 mules on farms, an increase of 1,276,000 horses and 785,000 mules in the last decade. In addition to this, we exported in the nine-year period ended June 30, 1919, 1,149,763 horses and 376,836 mules. — Wayne Dinsmore, secretary of the Horse Association of America.

Welding and Its Relation to the Repair Industry

By Lorn Campbell, Jr.,[1] (*Non-Member*)

Minneapolis Section Paper *Illustrated with* Photographs

WELDING is accomplished by the fusion of metals. Four general classifications can be made of welding in general; the forge, the oxy-acetylene or other gas processes, the electric arc and the thermit methods. All are used extensively and, while at first glance they might seem to overlap, in reality each has its own field at present. To attempt a discussion of all welding methods would require too much space and this discussion is consequently limited to the oxy-acetylene process.

Acetylene gas produces an extremely hot flame when burned with a proper proportion of oxygen gas; in fact, it produces the hottest flame known, its temperature being over 6000 deg. fahr. With this flame it is possible to bring any of the so-called commercial metals, cast iron, steel, copper and aluminum, to a molten state and thus cause a fusion of two pieces of like metal, so that the point of fusion will very closely approach the strength of the metal fused. If more metal of like nature is added, the union is made even stronger than the original. This method is called oxy-acetylene welding. It differs from what the average layman considers welding in the blacksmith's forge in that there is no blow struck to assist fusion. While the forge method is limited to wrought iron and steel which are detachable and of restricted size and shape, the oxy-acetylene process has, practically speaking, no such limitations.

The Repair Field

As a manufacturing process a wide field is thus opened. This discussion is, however, limited to the repair industry. I merely mention that on the Liberty engine there was 87 ft. of welding, the major portion of which was in fusing cast iron to steel. As a repair agent the welding torch has no rival. Whether it be a broken casting of iron, steel, brass or aluminum, a boiler or tank that has worn away in spots or an error on the part of the engineer, foundryman or machinist, the part can generally be reclaimed and made stronger than the original. Practically no manufacturing firm that is dependent upon machinery could think of being deprived of its oxy-acetylene apparatus, once it has learned its worth. In the past if a gear or casting broke, it probably meant closing the plant until a new part could be obtained, which would mean costly delay. With oxy-acetylene equipment and an efficient operator at hand, almost every emergency is provided for.

If an automobile frame breaks, the owner does not consider replacing it with a new one, because the labor cost and the cost of the new frame are prohibitive. The car is taken to the nearest welder or portable welding apparatus is brought to the car; the repairs are completed within a short time and the frame at the point of the break is made stronger than before. Locomotive frames are repaired in much the same manner, except that more time is required and perhaps extra operators. The important point is that in many instances no dismantling is required and the repair is permanently and quickly executed. For service in the field on tractors, trucks and other automotive machinery, a large percentage of trouble is occasioned by the loosening of rivets, which causes undue strains upon the transmission, engine and other working parts. The welding torch furnishes a concentrated flame which is played upon the loose rivets, and a hot-riveted joint is made. For brazing, pouring bearings, straightening bent members, welding the water-jackets of engines that have been frozen and the like, the welding torch plays a very important part. For salvaging, from the experimental laboratory through the entire factory the welding torch eliminates costly delays. If a casting has been improperly designed and falls short of certain measurements, additional metal can be added and lugs and other parts built up. This eliminates new patterns and the time lost in waiting for new castings. In the factory, machinists' errors can be corrected; if holes are drilled in the wrong place they can be filled up and drilled correctly. Broken taps and drills can be removed quickly and many other applications made by the wide-awake engineer.

Since practically every emergency is provided for, why should replacement parts be kept on hand? It is because of the lack of efficient operators. Again, why should good operators be lacking? This is because no means have been provided for the education of welders, and also because of the inability to test a piece that has been welded. It is surprising to learn how many good men have condemned the entire oxy-acetylene welding process, simply because some careless operators have turned out very poor work. Perhaps they were justified in this from their standpoint but, as an estimate, 75 per cent of those who claim to be welders add metal without any thought of fusing it.

How can welds be tested? I am aware of no general rule for testing each particular weld, but this should not prevent our learning the skill of the operator. It is a simple matter to provide a welder with test-bars of the metal generally worked and have him fuse these bars from one side only. As soon as they are cold, they can be sawed through the weld and an etching acid applied. A simpler method is to break the bar through the weld on an anvil, and inspect the fracture. If a good clean break presents itself and the crystals are uniform, it is reasonable to suppose that this operator knows how to fuse that metal and can be trusted to make similar welds. It is appalling to learn how few are concerned enough with the skill of their operators to test the results. If more care were exercised along these lines, both the welders

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A Huge Assortment of Tractor Parts Ready to Be Salvaged by the Oxy-Acetylene Welding Process

themselves and the overseers would benefit the industry as a whole.

The Oxy-Acetylene Apparatus

The oxy-acetylene process presents a very valuable means of making repairs and general salvaging, but to obtain the greatest efficiency it is absolutely essential that the operator be educated to know his tools, to be able to distinguish one metal from another, to fuse thoroughly the metals he is called upon to weld and to have a general knowledge of the contraction and expansion of metals where heat is applied.

The welding apparatus consists of two regulators equipped with pressure gages, two lengths of hose and a welding torch. The regulators are attached to cylinders of acetylene and oxygen gases and are used to reduce and maintain a uniform pressure of these gases for use at the torch. The gases are conveyed at reduced pressure to the high-pressure gage, to indicate the contents of the cylinder. There is also a line or working-pressure gage to show the gas pressure on each hose. When the gases reach the torch they are mixed. Combustion then takes place at the welding tip, which is fitted to the torch. Such an apparatus is called portable because of its movability, but there are other equipments wherein one or both of the gases are generated.

The many small parts in both the welding torch and the regulators must be kept perfectly clean. The regulators,

A Class of Soldiers Being Trained in the Art of Welding by the Oxy-Acetylene Process
Broken Taps and Drills Were Speedily Removed from Partially Machined Castings and Blowholes and Broken Parts of Various Vehicle Members Were Welded and Placed in Production After a Rigid Inspection

especially, have many sensitive parts which are constantly subject to much abuse. On the oxygen regulator a pressure of 2000 lb. per sq. in., when suddenly opened against a small seat, causes considerable trouble unless all passageways are clean. When the cylinders containing gas have been out in a storm, it is not an uncommon thing to find dust or rust in the cylinder valve. This should be blown out before the regulator is attached to the cylinder to prevent this foreign matter from being carried into the regulator. But very few operators observe this practice. To appreciate the welding apparatus thoroughly and treat it with respect, it is necessary that the welder become acquainted with his tools, so that he can make them function properly and work with real efficiency.

In the past, "flash-backs" were not uncommon. They caused much loss of time, loss of gas and inferior welds, but they are now avoided with modern apparatus. Flash-backs are caused by an improper mixture of the gases, which increases the rate of flame propagation so that the flame will flash back into the mixing chamber. Pure acetylene will burn very much more slowly than when mixed with equal parts of oxygen. When more oxygen is introduced the flame propagation is much more rapid. When an excess of oxygen is used, there is bound to be considerable trouble from back-flashing, but when sufficient acetylene is introduced into the mixing chamber, there is absolutely no chance for this lean mixture to occur. If the flame flashes back to the mixing chamber, both gases should be shut off at the torch immediately, the oxygen first and then the acetylene gas. In some torches the heating of the mixing chamber will cause a flash-back. With these it is necessary to shut off the acetylene and leave the oxygen valve just cracked, and then immerse the torch-head in water, dipping it slowly so as not to cause too great a strain. The oxygen will bubble out and prevent the water from backing up in the tip. If the flash-back deposits enough soot on the inside of the tip and the head to impair the working quality of the torch, the soot should be removed by using a soft wire, preferably of copper or some other material which will not mar the tip.

Metal Characteristics

To know how to weld, it is imperative that the operator first know the kind of metal he is to work upon. Few welders know the metals thoroughly. Many have trouble in distinguishing cast iron from malleable iron and cast steel and, as each of these metals requires a "filler-rod," it is necessary that their nature be determined in advance. Some welders depend upon the sparks given off by the emery wheel to determine the kind of metal they are about to weld. They will grind off their work, noting the sparks, choose their filler-rods and do the welding without any delay. Four simple ways are in common use to distinguish between cast iron, malleable iron and cast steel; by the cross-section of a fresh break, by an application of the welding torch, by the character of the sparks given off when the metal is placed against an emery wheel and by the chisel test.

Cast iron usually has some sand on its surface and its cross-section shows the grain to be fine, even and of a dull grayish color. The surface of malleable iron carries no sand and its grain is very fine; it is similar to that of cast iron but slightly darker in color. A very fine steel veneer is on all surfaces of malleable iron; it is much lighter in color. When the welding torch is applied to malleable iron a bright spark is thrown off which breaks in falling, showing that the outside material is steel. These sparks soon cease and the metal which is molten is covered by a heavy oxide or skin which recedes or draws away from the flame slightly, showing a very porous cast-iron interior. When brought into contact with the emery wheel, very luminous steel sparks, which break in falling, are given off first in the case of malleable iron, but they soon change to the dull-red spark of cast iron. When a chisel is applied to cast iron, the iron chips off; when applied to malleable iron the edge will curl up and then chip off when the cast iron is reached. The cross-section of cast steel shows a bright coarse silvery-gray grain. When the torch is applied a distinctively steel spark is thrown off, which is luminous and breaks in falling. When applied to the emery wheel, steel sparks are thrown off; when the edge is chipped by a chisel it will curl up.

The metal in the filler-rod should be the same as the metal to be welded, in practically all cases. Of the few exceptions to this rule, the principal one is that of malleable iron. The cast iron in the rods is of very good grade, generally much better than the piece to be worked. To permit the ready flow of the rod and eliminate oxidation as much as possible, 3 per cent of silica is used in the casting of filler-rods for cast-iron welding. Piston-rings and other scrap iron should not be used for filler-rods; they contain many impurities such as core-sand, dirt and grease, which will ruin the weld. It is disheartening to see some operators attempt to economize on the filler-rod. It is not uncommon to see the operator's reputation ruined and several dollars' worth of gas, the same amount of the welder's time and a few cents' worth of filler-rods wasted because of an attempt to substitute a filler-rod of very poor grade.

Fluxes

A flux is not used, as many suppose, to cement the filler-rod to the metal. It is used purely as a cleansing agent and can be likened to the acid in soldering. It does not act upon the metal until the latter has reached the melting point, but it then begins to break up the oxides and clean the surface. This action permits the metals to flow together more readily. A cast-iron flux is always used in welding cast iron, to break up the oxide, because the cast iron itself will melt before the oxide. No matter how hot the metal is, it will not flow together as long as this oxide is present.

To obtain the best results, reliable fluxes should always be used. The flux is generally applied by means of the filler-rod. One end is heated and dipped in the flux; enough will adhere to break up part of the oxides on the ordinary sized job. The flux is introduced between the flame and the metal, which should be at the melting point. The oxides will break up immediately and the metals will flow together, but it must be remembered that the flux has no action on cold or moderately-heated metals. The flux is used simply to clean the metal and break up the oxides and should be applied as often as is necessary to accomplish this result. All fluxes should be kept in air-tight containers when not in use, to keep their chemical contents in the very best condition. It is best to use only a small quantity of flux on the welding table at one time.

Practical Welding Methods

Oxy-acetylene welding is purely a fusing process. The most important points to remember in executing a weld are to eliminate the entire crack in the fracture and to add the filler-rod without changing the character of the metal. On thin pieces of metal it is possible to depend upon the force of the flame entirely to penetrate to the

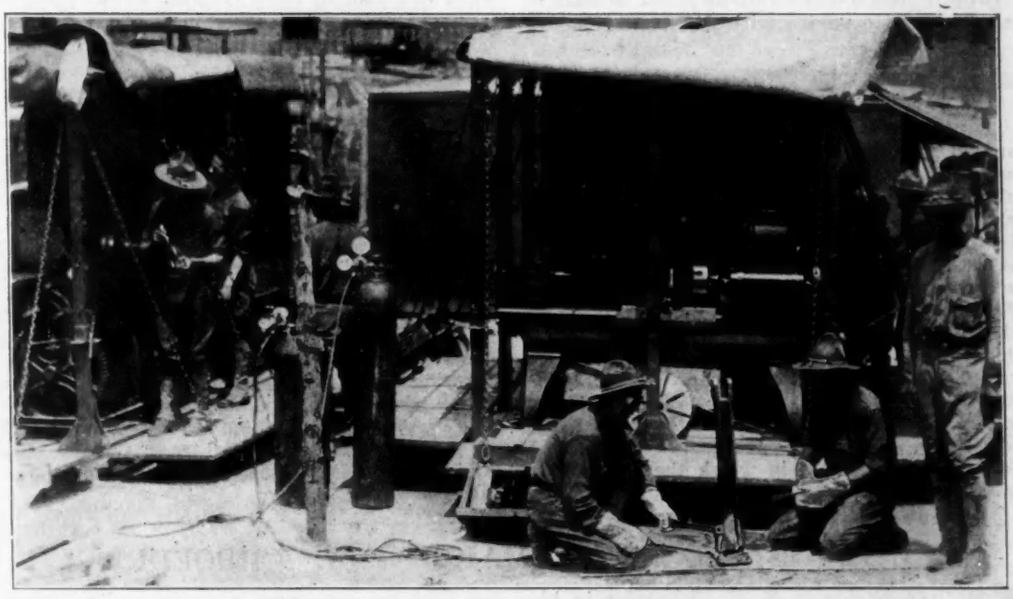
depth of the crack, but on work thicker than ⅜ in. it is well to vee out or remove some of the surface metal around the crack so as to penetrate to the bottom. Veeing means chipping or grinding off each edge at an angle of approximately 45 deg., so that the opening will form an angle of 90 deg. where the two pieces come together with the crack at the bottom portion of the vee. This should not be ground down to a knife edge; otherwise it will readily burn up. It is preferable to leave about ⅛-in. surface along the line so that the pieces will fit together and the proper alignment be obtained. If two pieces of cast iron have been prepared in this manner, the neutral flame of the welding torch is brought down so that the tip of the cone just licks the metal. The heat is not at first applied directly to the line of the weld but rather to the surrounding part. This is done to get the entire locality in a condition which will not withdraw too much of the heat from the line of the weld once the fusing is begun. If the tip will not produce enough heat to bring the metal to a red heat in a fairly short time, a larger tip should be used.

No set rule can be given as to the size of tip to be used on various kinds of metal. This depends largely upon the welder's ability and judgment. When the metal is brought to a red heat, the neutral flame or cone is brought into contact with the lowest portion of the vee, and held there until it is evident that the metal is melted on both sides. The filler-rod, which has previously been heated at one end and dipped into the flux so that some of the latter adheres to the end of the rod, carries this flux to that portion of the weld which is under way. Enough flux is blown off the rod into the weld to clean up the surface and permit the metals to flow together. The crack should be melted together along its entire length before any additional metal is added, because the elimination of the crack is extremely important. As soon as the metal begins to flow freely, the neutral flame should be raised a short distance from the work to control the molten metal better. To build up the metal to the original state along the line of the weld, or

THIS TRACTOR WHEEL WHICH IS OF AN OBSOLETE TYPE HAD A MISSING PART OF THE CAST HUB REPLACED AND FOURTEEN SPOKES WELDED IN LESS THAN 2 HR.

perhaps to reinforce it, the sides and bottom of the veed-out part are then brought to a molten state and held there, while the filler-rod which brings up more flux is stirred into this metal and the end melted off. In this way the flame does not come into direct contact with the filler-rod and is used only to keep the metal in a molten condition.

As much of the filler-rod can be melted off as is thought necessary to bring the weld to the normal condition of the metal, or an additional reinforcement can be built up if this is thought advisable. If care is taken in the above procedure, many of the blowholes and hard spots in the weld will be eliminated, for any impurities that might gather will be displaced by the melted metal and float to the top. Care should be taken not to permit any sudden chilling in cooling a weld of this kind, for this will tend to harden the weld. It is best to cool it



WELDERS OF AN ORDNANCE MOBILE REPAIR UNIT IN ACTION

The Portability and Ease with Which an Oxy-Acetylene Welding Apparatus Can Be Transported to the Scene of Action Is Illustrated. In Many Instances Broken Arms and Levers Can Be Welded in Place Without Dismantling Other Parts

slowly by burying it in slaked lime or ashes, or to wrap it with abestos paper to exclude the air from it.

The many causes for blowholes and hard spots in the weld can probably all be traced directly to lack of heat. Welding is a fusing process and heat is absolutely essential. Heat should not be used sparingly. Welders who would not think of throwing a cast-iron weld into cold water, for fear of chilling the metal, will often line up their work on large metal slabs or face-plates and make the weld in this position. The large body of metal conducts the heat away from the weld and chills it very rapidly. It is small wonder that a weld is hard and brittle if this method is used. Without exception the application of heat causes expansion and, likewise, there will be a contraction as the metal cools. Aside from the actual welding, or the fusing of the metal into a homogeneous mass, perhaps the greatest problem confronting the welder is the expansion and contraction of the metals. Whenever the ends, or even one end, of two pieces of metal which are to be welded are free to move, no difficulty will be caused by expansion and contraction, but if these ends are confined, preheating is necessary to reduce the expansion to a minimum when the welding flame is applied. Whether the entire piece is to be preheated, or only one member, depends largely upon the nature of the work.

Welding Costs

Costs play a very important part in repairs. The cost may exceed the price of a replacement part. Of course, if no such part is available it may be advisable to make repairs by welding. Conditions naturally vary in different shops. When the parts are heavy they will be preheated in some instances and will then require less gas and time to weld them. The time of the welder, the amount of gas, the material used and the overhead expense form a basis for figuring costs. The amount of gas taken for each job where individual cylinders are used can be determined from the gage on the oxygen regulator, if a chart is obtained from the manufacturer of the apparatus showing the ratio of the oxygen consumption to that of the acetylene. This ratio varies with different types of apparatus.

In acetylene cylinders an absorbent called acetone is generally used, which gives up the gas as required. A full cylinder can be used for some time without any noticeable difference in the gage reading and then, as it nears the empty point, the gage reading will drop perceptibly. It is therefore impossible to depend upon a high-pressure acetylene gage as an index to the contents of the cylinder. The only method known to check correctly the amount of acetylene gas on hand is to weigh the cylinder. The weight of 14½ cu. ft. of acetylene gas is 1 lb. and when the net weight of the cylinder is given the contents can be computed readily. A tag giving the net weight, or information for its computation, is generally found attached to each acetylene cylinder. For the oxygen cylinders, there being no absorbent used, the content of oxygen is indicated on the high-pressure gage. On the latest-type gage the contents are shown in cubic feet, in pounds pressure per square inch and in atmospheric pressure, to facilitate the computation of costs by the operator.

Great emphasis has been placed upon the fusion of the metals in making repairs because this is the keynote of successful welding; without fusion, permanent repairs cannot be realized. The method of testing the operator's skill, already described, is simple; yet it is often overlooked, which is the cause of many ineffective applications of welding in the oxy-acetylene industry. During the war we were called upon by the Ordnance Department to establish schools and to train welders for the various departments of the service. Approximately 2000 men were trained. An average of about twenty test welds per student was required before commercial welding was permitted. In personally inspecting these 40,000 test welds a very good idea was obtained as to the ability of the operators, many of whom had had considerable experience. With this still in mind, we are emphasizing the importance of thorough fusion. With proper training, the results are most gratifying. It is certainly to the interest of those dealing with and depending upon machinery and metal parts to give some time and serious consideration to the oxy-acetylene welding process as a method of making repairs and to the operators who use it.

FIRST ANNUAL AIR TOURNAMENT

THE first annual Army air tournament was held recently at Bolling Field, Washington. Its purpose was to acquaint the public with the progress, extent and limitations of aeronautics, together with an insight into what the future has in store in this line. There was a unique closed-course air race. The entrants in this event were lined up on the field and made a common take-off to negotiate twice a course around the Washington Navy Yard chimneys, the dome of the Capitol, the Washington Monument and the steel mill chimneys. This formed a somewhat triangular course of about 25 miles. The fastest time was 8 min. 47 sec. The contestants were at all times in full view of the spectators. The planes entered were SE-5's, DH's, Sopwith Snipe, Nieuport, Spad and Fokker.

There was an acrobatic contest in which the contestants had to perform two reverse turns, five loops, two barrel-rolls, a tailspin with six turns and a falling leaf, within 5 min. after reaching the prescribed altitude, in order to be rated.

Among the planes shown were to be found the Martin bomber that went around the rim of the United States, a D-7 German Fokker that came in from Middletown Depot, 133 miles, in 58 min.; a Martin torpedo plane, with a regulation Navy Whitehead torpedo suspended beneath, a Handley-Page, an SA-5, a Martin bomber with a Baldwin automatic cannon mounted on it capable of firing 120 1-lb. shells per min., a DH-4 equipped with German bomb releases and carrying German 100-kg. bombs, a DH-4 with eight machine-guns and practically no blindspots, a Breuget bomber with a Liberty engine, a DH-4 and a DH-4-B, a Vought, an Ordnance scout, a Spad, a Bristol fighter, a Curtiss JN with wireless equipment, an Avro and a Loening monoplane.—Air Service News Letter.

ALTITUDE RECORD OF MAJOR R. W. SCHROEDER

THE altitude attained by Major R. W. Schroeder in his record flight from McCook Field, Dayton, Ohio, on Feb. 27, 1920, is announced by the Director of the Air Service as 38,280 ft., if computed by the 1919 method of the Federation Aeronautique Internationale. It is pointed out by the Director that the maximum altitude attained according to the Bureau of Standards method was 33,000 ft. This, it is stated, is considered the more probable height. In making this flight a Le Pere biplane equipped with a twelve-cylinder Liberty engine and supercharge was employed.

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The Operating Speeds of Agricultural Implements

By Percival White[1] (*Member*) Semi-Annual Meeting Paper

WHAT is the most efficient speed at which to pull agricultural implements in the field? Probably this question is causing now more discussion than any other relating to the progress of the farming industry. Plowing and other operations, formerly carried out at 1¾ to 2 m. p. h., which is about the maximum rate for horses, are in certain cases being markedly accelerated as a result of the introduction of the tractor. In fact, some tractor manufacturers are advocating almost a doubling of these speeds. The controversy which has resulted as to the expediency of this change is one which lies near the heart of one of the world's greatest problems, that of the high cost of living. A decided increase in implement speeds, if it did not entail an excessive addition of power and labor, would make the world's yield of foodstuffs enormously greater. On the other hand, if such increased speeds are possible only at the expense of disproportionate fuel and labor costs, the movement is one which should be discouraged, before tractor and implement makers spend many more millions in attempts to apply to agriculture the rapid production methods which have been the big cause of America's supremacy in the manufacturing world.

The most encouraging aspect of this situation is the fact that serious attempts are being made to settle the matter by scientific tests. It is safe to say that such tests, properly conducted, and their results properly applied, would save a large amount of money. The agricultural implement industry has not, in the past, taken kindly to the introduction of even such accepted methods as scientifically conducted comparative tests for settling moot questions. Accordingly, the most discouraging aspect of the situation is the attitude of those who refuse to cooperate in such tests, or to lend them their support. There is, indeed, a tendency even for those manufacturers who are willing to conduct tests to enter them with a preconceived idea as to what their outcome will be. In other words, they seem to conduct the tests not to find out which course of procedure to follow, but to prove that their foregone conclusions are right and that the other fellow's are wrong. One cannot perhaps blame a manufacturer for this unscientific behavior, since an open repudiation of his policies would cost him dearly. Still, it seems more equitable for the manufacturer to bear this expense rather than the farmer, who has, in the past, been obliged to stand the brunt of most of the experimenting upon which the structure of power farming has been built. It is to be urged, therefore, that such tests, unless conducted by some entirely non-partisan group, should not be accepted as carrying any stamp of finality.

To settle the question of implement speeds would go far to determine the relative merits of the two types of tractor now contending for supremacy, the slow, heavy, high-powered machine, and the small, light, high-speed one. A given acreage can be covered for a certain cost either by the first machine pulling a large equipment of tools and moving slowly, or by the second machine pulling a smaller complement of tools at a considerably higher rate. Which outfit will finish the job most quickly, which will turn out the best work and which will pay the best net results in satisfaction? So large a number of variables enter the problem that an absolute optimum speed for all conditions will probably never be arrived at. Only the determination of relatively expedient rates can be hoped for. In the first place, the soil itself is a variable which has hardly a counterpart among the tests to which the average engineer is accustomed. It was considered marvelous when a slide rule was evolved for determining the cutting speeds of lathe tools, a problem in which a dozen or so variables were involved. But in this study of ours the changing facts are legion. Weather conditions, labor available, the personal equation, the size of the farm, the crop, the nature of the implement itself and many other things must be taken into consideration. Thus it will be impossible to draw any sweeping conclusions from a limited number of tests. Again, the agriculturalist cannot expect to standardize his operations to the same degree of nicety which characterizes those of the machine shop. On the other hand, the man who says, "My business is different" has become almost a by-word among industrial engineers who have shown in actual practice that a process of standardization is applicable to even the seemingly most inexact businesses. It is probable, therefore, that the standardization of agricultural operations can be carried further than most agriculturalists would have us believe. Once accomplished, such methods of procedure would repay a thousand-fold the initial expense of establishing them.

In arriving at the merits of the question of implement speeds, we must take into consideration (*a*) quality of results obtained, (*b*) operating costs, (*c*) first costs, (*d*) time saved, (*e*) labor factor, and (*f*) plow design. I have recently interviewed a considerable number of tractor and implement manufacturers upon these points, and to make more clear the elements involved, I propose to set forth under each of these headings whatever there is to be said on the two sides of the speed question.

Quality of Results Obtained

On the score of quality, much is claimed by both the adherents to high speeds and those who favor more moderate rates. At the risk of being arbitrary, we will assume that 3½ m.p.h. is high-speed plowing, and that 2 m.p.h. is slow speed. As a matter of fact, both these figures are perhaps a little high, if taken to represent an average mileage, including stops. In this connection it should be noted that to maintain an average of 3½

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m.p.h., a maximum speed of probably 4½ m.p.h. will have to be attained along the furrows. Here again, much misunderstanding may arise from lack of standards. The high-speed advocate insists that a better seed bed is produced when the share is moving rapidly than when it is operating at the speed established by the plow horse. He contends that owing to the greater impact the soil is more highly pulverized. This is supposed to do away with air pockets and permit a more homogeneous medium for the moisture and for the roots themselves. In reply to this argument, the low-speed man declares that pulverization is not by any means an unmitigated advantage. In fact, for fall plowing, pulverizing the soil is, in his opinion, to be avoided. The clods should not be broken up any more than is absolutely necessary. Plowing of the latter type is believed to hold the snow better, to drain better and to induce a more perfect aeration of the soil. Fall plowing is coming more and more into use, so that the merits of this question are well worthy of discussion. Others maintain that in a large number of cases high speeds do not pulverize so well as slow speeds. "The high-speed outfit," says a recent writer, "would pitch the furrow violently, leaving many clods and trash on top; while the slower outfit caused the earth to crumble as it turned." It is hard for the layman to understand how a four-mile-an-hour plow will pulverize better than a two-mile-an-hour job in one part of a field, while a few rods down the line just the opposite effect is to be observed.

High-speed adherents claim that rapidly moving bottoms cover better than slow ones, as a result of flinging the slice down with a force attainable only from high momentum. The rebuttal on this point is that the turning of the furrow depends primarily on the contour of the moldboard, and, again, that high-speed plows are as apt as not to fling the clods too far. Here, also, it is impossible to yield the palm to either side, for it is just another instance of the soil never being twice alike. It should, however, be noted in this context that in certain sections, such as most parts of England, it is not considered desirable to turn the furrow clear over, but merely to lay it up on edge. If it is safe to formulate any generality from the above, it is that since the soil is the great variable in every plowing equation, the plow itself ought to be the compensating variable. One would not think of using the same rake in a brass-cutting tool as in a steel-cutting tool. Then why only two or three different types of plow to till a myriad different kinds of soil? Every problem of plow speeds is likewise a problem of plow shapes. Another point under this head which tests should do much to throw light upon is whether the heavy, slow-moving tractor packs down the soil in such a manner as to stunt the growth of crops. It is asserted that fields plowed by such machines will, when grown, show depressions in the grain, caused by the stunted growth occurring in the grain which lies in the path of the tractor wheels. This effect is said to be particularly flagrant in certain parts of the Southwest, where the land will not recover for several years, or until deep plowing has been resorted to. The advocate of slow-speed operating maintains that this is gross libel, and offers to show by a mass of unsolicited testimonials that such packing is of the rarest occurrence. Obviously, there is some land which, though still arable, is so soft as not to support a large tractor without forming into deep depressions, but these instances are said to be greatly in the minority. As for packing under ordinary conditions, this, they say, does not take place, while any tendency of the sort can readily be corrected by inserting long spikes in the tractor wheels.

It should be noted that slow plowing does not necessarily imply a heavy tractor; but to compete with the high-speed outfit, the slow tractor must carry a proportionately larger number of plows. This means it must have more traction, more power and hence more weight. Another argument against high-speed plowing is that it can be accomplished only by a special plow, and that this plow would not do good work at the slower speeds, so that at the ends of the furrows the work would be of poor quality, since here the tractor would have to run slower for stopping and starting.

As to other operations besides plowing, there is perhaps much more to be said in favor of increased speeds, judged from the standpoint of quality of result. Certain sowing work, manure spreading and, to a limited extent, reaping operations, are said to give better results if carried on at high speeds.

Operating and Initial Costs

It is on this score that the slow-speed man brings his biggest guns into line. It is cheaper, he says, to pull four plows at 2 m.p.h. than two plows at 4 m.p.h. To prove this, he shows that the draft increases more rapidly than the speed, once you are traveling fast enough to scour properly. The horsepower required is next shown to run up in an even more pronounced curve, since the rolling resistance of the tractor alone becomes a decided factor above 2 m.p.h. In the above instance, twice as much distance would have to be traversed by the small outfit as by the large one. Twice as many turns would have to be made at the end of the field, and more time still would be lost in this way.

All this means increased fuel and increased cost. Possibly the labor cost may be less for a small outfit than for a large one, which carries a full quota of bottoms. But when it comes to breakdowns, the tortoise overtakes the hare. There seems to be little doubt that the high-speed mechanism will give out first. Not only does an engine operating at a large number of revolutions per minute under these trying conditions require more frequent renewals, but it is also reasonably certain to need more frequent adjustments and more vigilant watchfulness, while the chassis and the implements themselves run a far greater risk of damage from impact with the stumps, stones and other obstructions which are still found in a great proportion of all American farm land. It does not take much of a breakdown to cause half a day's delay, while, if a new part should be required, the damage might be really serious. And, aside from the considerations of cost, a plowing outfit which is always breaking down will prove a source of endless dissatisfaction.

Indeed, this is just the cue which the high-speed backer takes in answering the arguments just outlined. In other words, he believes too much stress is laid on the question of cost per acre. This he considers secondary to getting the work done while time and weather permit. "Make hay while the sun shines" is an agricultural adage which is now more timely than ever before. A few dollars more or less for fuel is as nothing compared with the benefit of getting the work done opportunely. The high-speed man is firmly convinced that he can get the work out more rapidly than the man who works slowly and covers a wide swath. His men are more alert, his outfit less unwieldy. He can get to the

field and back more quickly. Furthermore, he objects to the idea of carrying around so much weight. The whole trend of mechanical development, he says, has been away from heavy machines and toward light ones; the argument against the high-speed engine is fallacious; the high-speed engine has revolutionized the automobile business; the cumbersome car of the years ago has given way to the light machine, of which the counterpart can be seen in the light high-speed truck and in the small tractor itself.

If the balance is in favor of the slower unit for operating expense, it certainly favors the light hook-up when initial costs are concerned. With many farmers, it is a case of having a small light machine or none at all. It may be well enough to demonstrate the ultimate economy of the larger unit, but what does this avail the man who has not the money to buy it in the first place? The average farm runs considerably less than 100 acres in this country, and still less abroad. Such farms cannot afford anything but a moderate initial investment. Even in the Northwest, where the larger tractor has been most successful, its smaller counterpart is said to be making big inroads. Then there is the necessity for having more buildings to house the more cumbersome equipment, and this means more outlay still on the part of the farmer, who is, to begin with, a notorious example of the bad policy of having too little ready cash to do business with. But most farmers do not bother much about housing their equipment. They leave it out in the weather, which causes it to deteriorate far more quickly than actual use at any speed. Thus is the wear-and-tear argument also attacked, by showing that before even the high-speed equipment is worn out it will have become obsolete and ready for replacement, owing to the great advances now being made in all farming equipment. This last asseveration the slow-speed adherent does not admit. He doubts whether there will be any radical changes in implement design but thinks they will amount merely to a strengthening of present models. The increased initial costs he, of course, agrees to, but claims that the farmer is no longer to be satisfied with any equipment but the best, and that his recent prosperity has put him in a position where he can afford whatever equipment his business requires.

Both sides claim a time saving, and it is difficult to determine which has the stronger case. The significant fact, however, is that both realize the extreme importance of the time factor, which the agriculturalist so far has failed fully to recognize.

As to which type of farming it is easier to get labor for, there is as much argument as elsewhere. The high-speed man declares that no full-blooded American wants to drive any kind of a vehicle at 2 m.p.h., while his adversary protests that no man can ride a small tractor at 3 or 4 m.p.h. and last. With labor in its present state, this question becomes all-important. Yet it is a highly difficult one to answer, since it appears to be a variable second only in instability to that of the soil itself.

Plow Design

Advocates of the high-speed tractor claim that the whole future of their machines will be finally assured as soon as a suitable high-speed plow has been devised. This, they believe, applies equally well to other tools. They aver that the tests so far made to show the superiority of the slower units have been made with plows intended for horse speeds. For a given plow in a given soil we may assume that there is a critical speed at which its draft will be minimum. This will be somewhere above the rate requisite for proper scouring. It is possible that a bottom can be designed the critical speed of which will be higher than that of present patterns, without greatly increasing its draft. This could doubtless be accomplished without altering its general design but merely the contour of the moldboard itself. It is, however, logical to suppose that certain fundamental changes in design will have to take place in the plowing mechanism itself before a marked increase in speeds will become widely adopted. It would not, indeed, be strange if revolutionary changes should take place. That these should be the result of the development of an entirely new type of plow, rather than of a refinement of present patterns, is far from improbable.

In any event, it is upon the design of the moldboard that the question of plowing speeds largely depends, and hence also to a considerable extent the trend of the agricultural industry and its tributary manufactures. Indeed, there could hardly be an invention at the present juncture more widely beneficent than a plow which could be operated at double the present speed, without at the same time necessitating an increased expenditure of horsepower. Such a device does not lie beyond the realms of possibility. There are, however, many difficult problems involved. In the first place, a plow of ordinary type, if built to operate at 5 m.p.m., would probably not perform at all at 2½ m.p.h. Such a plow has been actually built and tested. Although it worked perfectly up to a speed of 8 m.p.h., it would not turn the furrow at 2 m.p.h. Such a plow would turn out bad work at the ends of the furrows, where starting and stopping would necessarily pull the speeds down. It might, accordingly, be necessary to provide mechanism for varying the pitch of the moldboard, assuming that the new device were of the moldboard type. If its rear extremity, for instance, were made of spring steel, and not made fast, its tendency would be to give way at high speeds, and to give only the requisite throw to the soil, while, when the speed slackened the spring would recover, making the moldboard bluffer, and giving the increased turning power necessitated at the slower rate. It seems, also, that the use of better materials, giving improved cutting edges, would be of benefit. There is also room for improvement in the design of jointers and other accessories.

Doubtless too much emphasis has been laid on the question of plowing, and too little on the other operations of power farming. In general, however, the same fundamentals apply to these as well. Radical changes in the implements themselves are required to keep pace with the ever-increasing speeds introduced by the tractor. A drill built to work at horse speed will not plant efficiently if driven at 12 m.p.h., as one machine did in a recent experiment. An alteration in the planting and covering mechanism becomes necessary.

Conclusion

There seems to be no unanimity of opinion among manufacturers as to the trend of the industry, as far as operating speeds are concerned. The tractor builders seem to frame their answers to accord with the particular models they are marketing, although it is only fair to state that many of them are now producing both types, to be ready for any eventuality. As for the implement builders, they are mostly so absorbed in supplying the immense demand that they have had no time to devote to an intensive study of the speed problem. Most of

them, however, are redesigning their implements for tractor purposes, and one or two, instead of converting their horse-drawn machines by strengthening and stiffening them to withstand the increased strains, are offering entirely new machines, solely for power use.

Among some manufacturers there exists the opinion that plowing speeds of 5 m.p.h. are at hand. Among others it is thought that speeds will not increase above that of horse-drawn implements. The conservative idea, however, accepted by 90 per cent of the people interviewed is that an acceleration in implement speeds is bound to come; but that its coming will be gradual and slow. Some welcome this change, others dread it, but all seem to expect it. The wisest are preparing for it. In general, it seems hardly possible that the acceleration of every human activity should not have its effect upon farming operations, especially at a time when a marked increase in agricultural production is the only thing which now stands, in the lives of millions, between them and starvation. In manufacturing, we have come to regard speed and increased production as practically synonymous. It is thus all the harder to understand how the farmer can cope with the unprecedented demands upon him without arriving at identically the same conclusion, although possibly by a different way of thinking.

Frederick W. Taylor, the man who did the most to bring the time element into industry, said that scientific management is applicable to every kind of business but agriculture. Yet the time is already upon us when the most highly perfected modern methods are being used to increase the yield of crops. The production expert is going back to the land. So is the scientist. So should the engineer. There is no place where his skill is more greatly needed, no field which offers him better opportunities. The day of the farmer-inventor has been one of the most notable in the history of American achievement, but its sun has set, and the day of the farmer-engineer is at hand.

CARBURETION AND DISTRIBUTION OF LOW-GRADE FUELS

(*Concluded from page* 24)

tageous from the standpoint of fuel economy, power and low cost of upkeep. It is not claimed that there is anything radically new in this; its use is merely recommended. Where the whole manifold was external and the cylinders cast separately, the change from gasoline to kerosene resulted in the horsepower falling as low as 45 per cent of the gasoline output. By changing the manifold to the type shown, the horsepower output using kerosene has been developed to within 8 per cent of that when using gasoline. Further, the output when burning gasoline in the new manifold increased nearly 10 per cent above the previous test. This was on engines having a bore of over 7 in. A number of demonstrations of this kind have been made. There was always a marked reduction in the fuel consumption because all of the cylinders were pulling alike. There is always a greater flexibility of engine performance with this manifold type and it permits the use of kerosene or gasoline with advantage. Used with kerosene, it very largely eliminates the knock. It has been my experience that a great part of the knock which developed in a four-cylinder engine was due to a lean mixture in some of the cylinders. When this was corrected by even distribution in many instances the knock disappeared, or it was possible to increase the power output even when it was necessary to reduce the compression when changing the manifold. In other words, in these cases a compromise between manifold depression and manifold turbulence on the one hand, and compression on the other, has made possible the use of extremely low-grade fuel and increased the power output. It has done so well with some engines upon certain low-grade fuels with an initial distillation point of 300 and an end-point of 550 deg. fahr., that the power output has compared well with the gasoline output on the same manifold when using the fuel converter illustrated. In laying out a job for this style of manifold, no fixed rules of velocity can be laid down, but in general most manifolds built in the past will stand the reduction of area imposed by the chokes at the tees and beyond the turns, and still gain in power. In a number of instances where the manifolds are already very small, it may very possibly be necessary to enlarge the manifold to some extent so as to utilize this principle as a means of obtaining correct distribution of the fuel.

AVIATION POSSIBILITIES IN SOUTH AMERICA

SOUTH AMERICA has been keenly alive to the possibilities of aviation both from a military and commercial viewpoint. The enthusiasm for aviation received a start during the war and has been accelerated since the armistice by the arrival of aviation missions from England, France, Italy and America. The British interests have been by far the most active and have paved the way in practically every South American country toward the establishment of permanent commercial air routes. That these missions mean business cannot be doubted by anyone as they have trained engineers, flying personnel and complete equipment in every country, and such types of planes as the Handley-Page bomber, Vickers, Vimy, DH-9, etc., are in active operation in many South American countries. The success which these missions have met with has been largely due to the fact that they have secured concessions over certain routes, mail contracts and last but not least, training South American personnel in the art of flying.—Air Service News Letter.

Controlling and Atomizing Fuel by Variable Engine Pressures

By JOHN G. WILLET[1] (*Member*)

BUFFALO SECTION PAPER *Illustrated with* DRAWINGS

THERE is hardly a subject at present more vitally interesting or of greater importance to the automotive and the petroleum industries than the fuel problem. The efforts of designers to use kerosene as an engine fuel have been abandoned by many, including myself, in favor of a type of fuel that contains the combined gasoline and kerosene fractions of crude petroleum. This type of fuel will increase the supply and extend the period preceding a shortage. The efforts of those trying to solve the kerosene problem will not be lost, as the heavy ends of this combined gasoline and kerosene fuel must be treated in a carbureter the same as kerosene. The use of this type of fuel will be beneficial to the refiners in many ways. It will eliminate to a great extent the present cumbersome method of refining, handling and marketing two fuels, and substitute one fuel.

With the increased use of natural water-power, which is converted into electricity, the demand for kerosene for lighting has fallen off considerably. On the other hand the demand for gasoline is increasing. In the early days gasoline was considered a waste product of the crude oil and there was little demand for it. Thousands of gallons were wasted, there being no market, but with the appearance of the automobile a market was created. The automotive industry has grown in size until now it almost equals that of steel. In 1910 there were 15,000,000 bbl. of gasoline consumed, while in 1919 there were 95,000,000 bbl. used, which shows a steady increase in the demand for this fuel. At present there are more than 7,500,000 motor vehicles registered in the United States. In addition to the great number of automobiles used the tractor is now used to a large extent and the number is increasing each year. Another vehicle now entering the field of gasoline consumption is the gasoline trolley car.

The tremendous demand made by the automotive upon the oil industry has forced the refiners to raise the end-point of gasoline from 300 deg. fahr. in 1918 to 437 in 1919, the end-point being the temperature at which the final part of the fuel is vaporized. The lower the end-point the better the gasoline, but with a low end-point we cannot get the quantity of gasoline from the crude, so it is necessary to raise the end-point to obtain a sufficient supply to meet the demand. If the volatility of gasoline had remained the same as it was a few years ago, there would not have been enough gasoline to supply the demand. In the early automobile days the yield of gasoline from the crude oil was about 5 per cent; at present, raising the end-point and lowering the quality of the gasoline, a yield of 25 per cent is obtained.

In the past the increasing demand has been met principally by changing the quality of the gasoline and by using a larger percentage of crude oil, but this condition has about reached a limit, unless carbureters and engines can be designed to use the heavier fuel. As the larger portion of the fuel is made up of the heavy ends, which are not volatile at normal temperatures, it can be seen plainly that it is difficult to turn this fuel into a satisfactory gas in the existing type of carbureter, which was designed primarily to function with a fuel of greater volatility. Only the lighter elements in the present fuel are volatile and have any tendency to vaporize.

The present fuel has two good features in its favor: there is a saving due to less loss by evaporation while in storage and it contains more heat units. It therefore is capable of giving an increased mileage per gallon, if the carbureter can vaporize it. The present heavy fuels are safer to handle, as they are not so volatile, and the number of explosions or fires are very few compared with the vast quantity of fuel handled.

As a result of lowering the quality of the fuel by adding the heavy ends of non-volatile elements to increase the supply, the oil refiner has imposed increased demands upon the carbureter, which have been met partly by better-designed spray jets and higher air velocities and partly by the application of heat to the intake manifold. In the last five years there have been several new carbureters put on the market and many improvements made on the old types, but at present they are all operating on the same principle, that of atomizing the fuel by the velocity created by the vacuum of the engine and this is not high enough to atomize the heavy fuels thoroughly at all speeds.

The application of hot spots to intake manifolds has helped to assimilate the heavy fuels by boiling the heavy ends into a vapor, but with all these improvements the following troubles still exist: (*a*) crankcase dilutions, (*b*) hard starting in cold weather, (*c*) poor acceleration, (*d*) puddling or loading of the intake manifold at low speed, and (*e*) an inability of the existing types of carbureters to furnish the proper mixture of air and fuel to meet the variable loads of the engine.

A varied assortment of engine fuels is now on the market, due partly to the varying nature of the crude oil from which they are taken and partly to the different methods used in refining. A great percentage of the fuels now used is made up of either cracked fuel oil and kerosene, or low-grade straight runs blended with casing-head gasoline. The blending process is susceptible of considerable improvement. A fuel not properly blended will cause considerable trouble in a carbureter which is bolted directly to the cylinder block. The heat conducted from the cylinder block to the float-chamber will cause a boiling action which produces gas pockets. These form in the float-chamber and have a tendency to force the fuel back into the line, which causes an intermittent running of the engine. This effect is noticeable from a galloping action of the engine, while idling, and at open throttle the engine will slow down as if short of fuel and then at times regain its speed. If the fuel is properly

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blended, an engine will start readily and show very good pulling ability with no erratic running effects.

Crankcase dilution and intake-pipe loading clearly indicate imperfect atomization.

The majority of the carbureters now on the market employ two or more spray jets to secure better atomization. In 1907 I designed a multiple-jet carbureter which had fourteen jets that were opened progressively by a piston throttle. It was used very successfully on racing motorboats. An operator of one of the boats succeeded in increasing the revolutions per minute by mixing 25 per cent of kerosene with the gasoline, which tested about 74 deg. Baumé. The results obtained by mixing kerosene with high-test gasoline demonstrated that more power can be secured in the heavier fuel, provided that the carbureter can atomize it. The result obtained by hot spots would be materially increased by better atomization, as the time element plays an important part in its operation. The period is very limited from the time the fuel leaves the spray jet until it reaches the engine cylinder, and the finer the molecules of fuel the less the time required to vaporize it.

Controlling the Fuel

Considering the method of controlling the proportions of gasoline and air as used in the present carbureter, where the amount of gasoline is controlled by the flow of air through the carbureter, let us see what proportions of gas and air will meet the variable demands of the internal-combustion engine. We have all had the experience of starting out with an automobile on a cold day. After starting the engine it seems to run well in the idling position, but as we engage the clutch and apply a load to the engine we very often stall it, because of not having a rich enough mixture. We may start again and run satisfactorily in first speed and yet have difficulty in second speed. By following a car operating on benzol mixture it will be observed that every time the car reaches its momentum and the load on the engine decreases, a black smoke will be emitted from the exhaust pipe, but that this will clear up immediately upon acceleration, which increases the load on the engine. Having noted these results it will then be observed that the engine requires fuel in proportion to the load it carries, regardless of speed. To secure good acceleration it will be evident that a very rich mixture is required, but that after a car attains its momentum the gasoline can be reduced. This can be plainly observed on a car equipped with a dash adjustment on the needle-valve, controlling the flow of gasoline to the jet. One make of car in particular is so equipped, and has won several economy tests of national importance.

This condition has also been met partly by the addition of a well, or compensating jet, located between the needle-valve and the ordinary jet, which fills with gasoline at low speed but empties into the main supply when sudden demands are made upon the engine. The jet at this time has approximately doubled the amount of fuel to be atomized; only a very short time is available to perform this duty and, together with the low air velocity, it is not surprising to find that the fuel has not been properly atomized and has been delivered to the engine in practically a raw state. Another indication of the variable mixtures required by the engine is shown by running on a level road with a properly-adjusted mixture and then going down a grade. The popping in the muffler indicates an over-rich mixture, so rich that the engine is unable to burn the same mixture that it will handle under load. In adjusting the existing carbureter to handle the heavy loads it is wasting fuel on the lighter loads. This same condition exists every time the throttle is suddenly closed, which happens frequently. This is not only wasting fuel but causes an accumulation of carbon deposits. In an automobile engine where the load is fluctuating almost continuously this waste is considerable.

With a check valve placed in the position of a priming cup in the cylinder and a tube connecting to an air gage of about 50-lb. range located on the dash, a small escape hole drilled in the connecting tube will prevent the building up of too much pressure in the tube and will show the variable loads. A trip in a car equipped with this gage will show high pressure when accelerating, or pulling up steep grades, and on down grades the pressure will drop to less than 1 lb., the complete range of pressure being approximately ½ to 30 lb. per sq. in. This pressure range is independent of engine speed. The action of the gage is quite similar to that of the ammeter on an electric automobile. The action of the gage shows that the existing type of carbureter, where the fuel is governed by the air entering the engine, is entirely inadequate to meet the demands of the engine.

Consider an engine speed of say 600 r.p.m. in an automobile. There is a wide range of loads from coasting down hill, where the car is pushing the engine, to climbing a grade, where the full load is required. With the existing type of carbureter the same quality of gas would be supplied, whereas a very lean mixture is required in the case where the car is pushing the engine and a richer mixture where the engine is carrying the full load. The carbureter is naturally adjusted for a mixture to meet the heavy load and it is evident that fuel is then being wasted on light loads.

Horizontal Versus Vertical Carbureters

With the horizontal type of carbureter mounted in the same plane with the intake manifold, some of the trouble experienced is that, in starting, a large quantity of fuel may be drawn from the carbureter into the intake pipe, whence it runs into the cylinders in a raw state and fouls the spark-plugs. This condition has been met partially by late timing of the inlet valve, so as to give the fuel an aspirating or pulverizing effect by the valve opening under a partial vacuum.

After watching engines with both horizontal and vertical carbureters closely, I believe that the horizontal type will in time be superseded by the vertical for the following reason: The fuel is composed of light and heavy fractions, the former being of course less volatile. The vertical carbureter thus has a tendency to alleviate this condition to a great extent by retarding the heavy fractions from entering the cylinders. As the heat of the engine and the temperature of the intake air increase, the heavy fractions of the fuel will be delivered to the cylinders at a time when the engine is in a condition in which these fractions can be used with greater success.

Water is not considered a volatile liquid; yet about 75 per cent of our present gasoline will not boil at a less degree of heat than the boiling point of water; and still we try to start a cold engine with this fuel. We close the choker valve tightly, which shuts off the air, and then crank the engine. Is it any wonder that we find the oil in the crankcase contaminated with a great quantity of fuel, which renders it unfit for lubricating purposes? In a car driven by anyone who makes frequent stops and drives in all kinds of weather, it is not surpris-

ing to find that the life of the engine is very short. In some makes of automobiles the oil is so diluted in about 200 miles that it must be replaced with fresh oil. In redistilling this oil and removing the heavy ends of the gasoline, the lubricating oil is found to have all of its original qualities. When a crankcase is drained, the lubricating oil and the heavy ends of the gasoline are thrown away in most cases. Many drivers run their cars for months without changing the oil, and at the end of the season condemn and trade them, expecting to eliminate their troubles. Any good grade of engine oil should retain its lubricating value for at least 1000 miles of running, so the condition mentioned shows that we are wasting not only fuel but lubricating oil.

The heavy ends of the fuel have caused trouble in ignition. In some of the engines now on the market, it is almost impossible to start in cold weather without fouling a spark-plug. In the design of new engines the location of the spark-plugs should be given careful attention. If they are placed where the incoming charge hits them directly or on a level with the top of the piston, any raw fuel will foul them immediately. Many times the oil is blamed for fouling the spark-plugs, while in reality the fuel is at fault.

Lubricating oil is an insulator, while certain gasolines act as conductors of electricity. The heavier the ends in the gasoline the slower they are in burning, even if they are delivered to the combustion chamber in the form of gas. To overcome this slow burning, several manufacturers have developed and are using what is termed dual-double-ignition. By the use of two spark-plugs, firing simultaneously and igniting the charge from both ends, combustion takes place in about one-half the

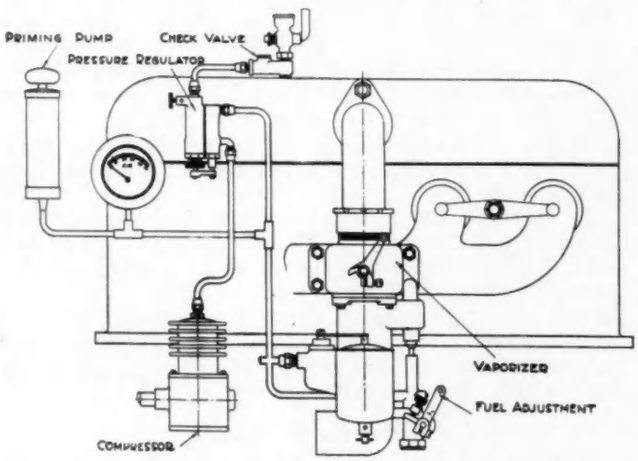

FIG. 1

time consumed by the use of the single spark-plug. With this improvement in ignition the heavy or slow-burning fuels will equal the performance of the lighter fuels which were formerly obtainable.

SPECIAL-TYPE CARBURETER

With the existing troubles of the present fuels known, together with the experience gained in the development of several carbureters, both gasoline and kerosene, I determined to produce a carbureter with the following qualifications:

(1) A jet that will thoroughly atomize heavy fuels under all speeds and conditions, including low temperature

(2) A vaporizing device that would supply enough heat at low throttle and could be adjusted for various grades of fuel, or for weather conditions

(3) Means for controlling the fuel supply so that mixtures of various qualities will be delivered to meet the varying loads of the engine

Such a carbureter, as partly developed, in which the fuel is controlled and atomized by a variable air pressure, is shown in Fig. 1. The pressure air used for atomizing is supplied by an engine-driven compressor and the amount required is fairly small, the compressor used being of standard tire-pump dimensions, with a maximum pressure of 15 lb. per sq. in. This pressure air is controlled by a pressure-regulating valve as shown in Fig. 3. The pressure regulator consists of a cylinder with a piston, which is actuated by the variable pressures in the combustion chamber. Connected to the piston are a shaft and a yoke which transmit the motion of the piston to a metering pin which, in turn, controls the output of the compressor, thereby delivering a variable air pressure to the atomizing jet corresponding to that in the cylinder.

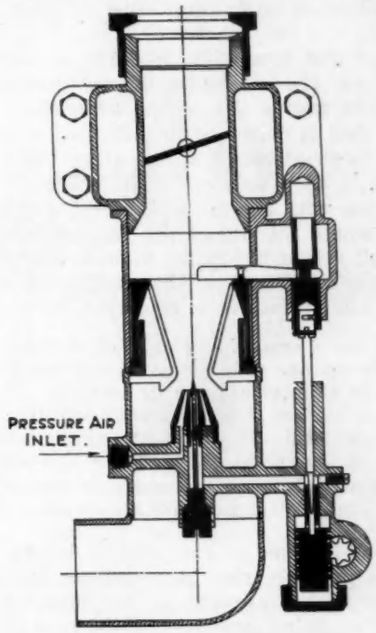

FIG. 2

The range of pressure in the cylinder varies from about 2 to 30 lb. per sq. in. This range can be changed by regulating the needle-valve, which controls the outlet of the cylinder. The reduction of the maximum air

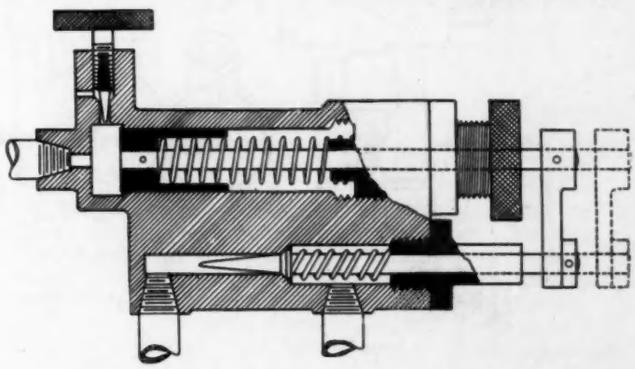

FIG. 3

pressure of 30 lb. per sq. in. in the combustion chamber to 15 lb. per sq. in. at the atomizing jet is due to the range of the jet as the pressure air controls the fuel. The maximum of 15 lb. per sq. in. appears to be a satisfactory range at the jet to supply the proper quantities of fuel to the engine. This pressure range will thoroughly atomize the fuel, heavy oil or lubricating oil, without allowing any liquid fuel to pass the capillary needle tip.

The fuel and atomizing jets are located beneath the venturi tube, the air being drawn through the carbureter by the engine, having no aspirating effect on the jet. The fuel is delivered into the throat of the venturi tube in a finely-atomized spray, mixed with the pressure air which is used to atomize it. This rich mixture is then blended with the air in the venturi tube and auxiliary air around the top of the venturi tube, so that the fuel is well mixed before it reaches the throttle. Here it is further vaporized by the application of heat.

An auxiliary air-valve is employed for two reasons,

(1) To use a small-diameter venturi throat to keep a high velocity at idling speed and extend the blending to as large an area as possible. The auxiliary air is blended at high velocity and distributed over an extended surface, as the circumference of the top of the venturi tubes makes this possible

(2) The air-valve carries a metering pin which corrects any error in the pressure regulation

When the engine is carrying a heavy load at low speeds, the pressure rises and delivers too much fuel in comparison to the amount of air entering the engine. The air-valve, being governed by the flow of air, then returns to its seat and in turn cuts off the fuel. The air pressure remains high during this period, which eliminates any loading. The air-valve is prevented from fluttering by a dashpot surrounding the skirt of the valve. Fuel is fed to the jet from a float-chamber of conventional design. Surrounding the fuel jet is an annular tapered air-jet that directs the atomizing air which is under pressure. Located in the center of the fuel orifice is the capillary needle which feeds the fuel in a thin stream, due to its capillary attraction, to the tip of the needle. The pressure air in passing by the fuel jet at high velocity creates a vacuum at the top of the fuel orifice, which lifts the fuel. The higher the velocity, the more fuel is lifted.

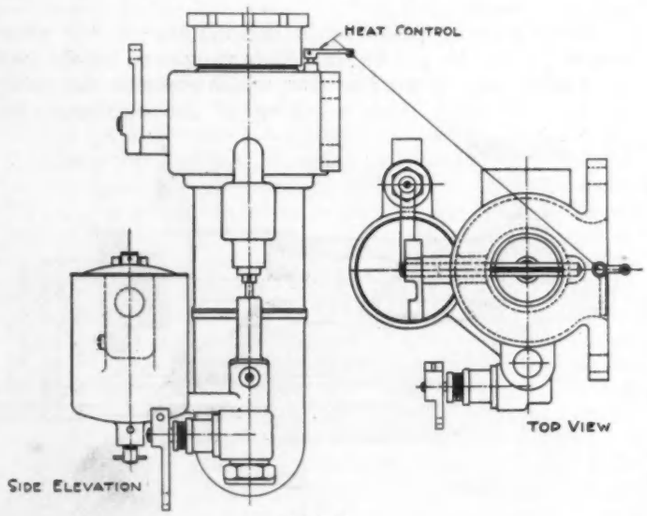

FIG. 4

The fuel, fed off the capillary needle point in a fine stream, is met by the high-velocity air at different angles and it is finely atomized. The high velocity of the atomizing air has some supercharging effect, which is noticeable at idling speeds when the air entering the engine is at low velocity, the atomizing air being sufficient to carry the fuel as far as the throttle without the aid of the regular air supply. This action is proved by the fact that little fuel is used at idling speeds. A six-cylinder engine has idled for several minutes on a float-chamberful of fuel.

THE VAPORIZER

The throttle is located just above the venturi tube and air-valve, and is of a conventional butterfly type. It is situated in the center of a hot spot, secured by jacketing the carbureter header and the use of exhaust gases passing through this jacket. The entrance to this jacket is controlled from the dash, which gives a wide range of heat, from a small amount absorbed by contact, when the damper is closed, to a full flow of exhaust gases through this jacket. Heat is obtained very quickly in starting, as this by-pass valve when opened diverts almost the entire exhaust from one-half of the cylinders of a four or six-cylinder engine to the vaporizing jacket. The throttle shaft is carried into the exhaust jacket and conducts heat to the throttle-valve, giving a vaporizing rather than a condensing tendency to the finely atomized spray.

The metering pin, which is operated by the air-valve, is located in a vertical barrel mounted on the side of the carbureter body, and connects with the duct which carries the fuel from the float-chamber to the fuel nozzle. The metering-pin seat, located directly beneath the metering pin, is adjustable from the dash. It is raised or lowered by the action of a pinion and rack gear, the rack gear being a part of the valve seat and the pinion receiving its motion through levers operated from the dash. The carbureter is not fitted with a choke valve such as is used on most carbureters, its place being taken by a hand air-pump, which is operated from the dash and connects with the pressure line.

In starting, the metering-pin seat is lowered, which increases the fuel supply. The air-pump is then given a stroke, which delivers a charge of finely-atomized fuel blended with a small amount of air. This charge is delivered at a high velocity, therefore carrying the charge well into the intake manifold, which gives an explosive mixture with a minimum amount of fuel; also preventing the cylinder from being flooded with raw fuel.

ADVANTAGES GAINED

With the pressure type of jet, many desired results are obtained. While the pressure system increases the number of parts in the carbureting system, this is more than offset by the results obtained. The pressure system makes it possible to handle the present high end-point fuels and it may be possible to use successfully fuels with even higher end-points or, in other words, to use more kerosene with the gasoline. This will increase and prolong the fuel supply which is of vital importance to the automotive industry. If enough air pressure is applied and the jet is carefully designed, the fuel will be thoroughly pulverized and it will be impossible for any fuel in the form of a coarse spray to pass the jet. After leaving the jet the globules are so small and surrounded with a film of air that they are easily kept suspended in the airstream. By reason of their minute size and mass they will follow the airstream and will not puddle at the

turns, as the inertia effect of the fuel is greatly reduced by fine atomization. Having overcome the inertia forces, in combination with the high velocity of the atomizing or pressure air and the ability to pulverize almost instantly any necessary quantity of fuel, excellent acceleration will be obtained with a minimum amount of fuel.

A thrust of the hand-pump fills the intake pipe with a finely pulverized fuel combined with the air used in atomizing it. This makes it possible to obtain a quick start, which eliminates the fouling of spark-plugs and dilution of the lubricating oil; it also makes little demand upon the starting battery. The results are practically the same at low temperature. By shunting a large quantity of the exhaust gases around the throttle chamber, very good vaporizing results are secured. At low throttle, when the most heat is required, the exhaust produces the least; but by mounting the throttle chamber as shown in Fig. 1 a good share of what little exhaust exists is made use of. The throttle deflects the intake gases against the heated surfaces and supplies heat to the intake gases in the proper proportion. The smaller the throttle opening, the closer the mixture is deflected against the heated walls. At full-throttle opening the gases are not deflected against the heated walls and, as the heated area is small, little heat is absorbed, thus a cool mixture is provided at open throttle, which means volumetric efficiency. As the fuel is finely pulverized, very little heat is needed around the inlet manifold to keep it from condensing. By having the vaporizer connected directly to the exhaust manifold, heat is obtained very quickly in starting.

If the heavy ends of the gasoline which cause so much trouble are passed through the high-pressure atomizing jet and then through the vaporizing device, they are transformed into a vapor which, while probably not a dry gas, will burn explosively in much the same way that grain dust or pulverized coal burns. With no deposition of the fuel, the distribution of the mixture is a simple problem. The good results obtained from controlling the fuel by the pressures of the engine are shown not only by increased economy but by the elimination of over-rich mixtures which cause undue carbon deposits.

In a road test with a car equipped with a carbureter of the pressure type, but having only a crudely-designed jet and practically no air control, the following results were noted. Controlling the fuel by the variable loads carried by the engine shows a saving in an automobile type of engine of about 50 per cent. In the case of an engine on which the load is fairly constant, the percentage of saving is much less. The saving mentioned is found in a road test and not in dynamometer test, as the greater percentage of saving is obtained in the automatic cut-off of the fuel when an automobile is coasting or carrying light loads.

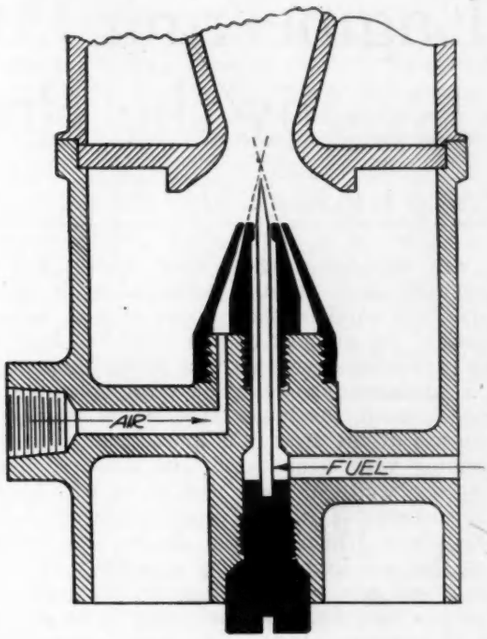

FIG. 5

There is no tendency toward loading in the intake pipe. A car operating on a mixture of three-quarters kerosene and one-quarter gasoline was driven more than 2 miles with the throttle closed and a retarded spark; it then accelerated rapidly with a clean exhaust. The large percentage of kerosene used would have shown a smoky exhaust if there had been any tendency to load. Good acceleration showed that the fuel was well atomized and fed in the proper proportion.

The tendency of the high-velocity air and fuel passing through the intake airstream, is to speed up the air, because of injector action, thereby producing some supercharging effect, and reduced sectional area of the manifold, which has been used extensively to obtain the same results, is obviated. A relatively small amount of heat is required as a result of the fuel being finely pulverized, so that a cooler charge can be delivered to the engine, resulting in better volumetric efficiency.

The results so far shown by the use of the pressure system are very promising. They indicate that some time the less-volatile fuels can be used and that probably better economy and more power can be secured, due to the higher percentage of heat units contained in the heavier fuels.

THE UNITED STATES A CREDITOR NATION

U. B. COLVER, a member of the Federal Trade Commission, said recently in an address:

From a debtor we have become a creditor nation. Before the war $10,000,000,000 of our securities was held abroad and to pay a dividend of 4 per cent to the foreign security holders there was created, automatically, a market for $400,000,000 worth of our goods. As a result of the war we have brought back that $10,000,000,000 of securities and have loaned $10,000,000,000 across the ocean. During the first 144 years of our national life, we have wasted our forests and our minerals; we have thrown hundreds of millions of acres of land away. We have disdained anything so slow as inland water transportation, while we built thousands of miles of paralleling railroads, and now we are breaking the backs of those railroads by displacing quick-moving high-rate freight to care for mountains of non-perishable low-rate commodities.

Engineering Possibilities as Indicated by the Progress of Science

By Charles F. Kettering[1] (*Past President*) Pennsylvania Section Address

IT will be interesting to view in perspective some scientific facts from a purely scientific standpoint, and then to show their application to some of the problems of the automotive industry. We have reached a point in this industry where the public begins to regard it as a fundamental one. The term "pleasure car" is being abandoned, the truck is becoming very important and the use of the tractor is increasing. The industry is becoming very complicated. In addition, there is a threatened scarcity of fuel. But along with this industrial development a parallel scientific development is in progress, from which we can derive information and apply it, that will simplify many apparent difficulties.

The present rate of development in the mechanical industries has been brought about largely by our present ability to measure things. The whole system of interchangeable manufacture is based upon our ability to make accurate measurements. In the early days of mechanics a shaft was measured with an ordinary pair of calipers. The mechanic who could guess most closely had something uncanny about him; he had a delicacy of touch that no one understood. Then came the ordinary C-type micrometer, which would measure so much more accurately that two mechanics could agree approximately on what a given diameter was. With that system of measurement it was thought satisfactory to measure down to 0.0005 in., but in modern mechanics this is a large dimension. With the C-type micrometer a certain amount of skill is necessary so that it is not screwed up too tight, which would spring the frame, and a nice touch is required to make accurate duplicate measurements. Then came the ratchet head, which facilitated measurement by supplying a touch which was the weakest part of the micrometer. But after the Johansson blocks were devised, which are guaranteed accurate within 0.00001 in. plus or minus, by using the indicating gage an inexperienced girl could measure with accuracies that went into 0.0001 in. very easily. By using the standard gages of that system the number of people who can measure accurately has been multiplied tremendously. Of the thousands of pieces that enter into automobile construction, many are accurate within 0.0001 in., such as ball or roller bearings. Even such measurements are relatively large. A machine known as a compound interferometer has been devised which can split an inch into millionths and a good one will measure within 0.00000005 in.

The need of being able to measure within 0.00000005 in. is that we have thus been able to at least visualize certain fundamentals in mechanics that we never knew before. Suppose a shaft 10 in. in diameter and 10 ft. long, 5 ft. molded into a concrete block and 5 ft. protruding, forming a fairly rigid bar. If an ordinary fly lit on the end, the shaft would bend. With one thumb of a compound interferometer placed upon it, when the fly lit one could see the shaft bend and vibrate. The lesson is that material has absolutely no strength to resist force until deflected, and it must deflect an amount sufficient to form a reaction equal to the force applied to it, no matter how delicate that force may be. This is so fundamental and has been so lacking in the design of machine tools and the making of accurate parts, that the whole progress of the automobile business has been in making heavier and heavier machines to do the lighter work. We are just getting sense enough today to make machines large enough to come at least within one-half the degree of accuracy claimed for the parts. The smaller the parts, the more accurate they must be. More weight and strength must be put into the machines; otherwise those small forces that are apparently negligible simply deflect the apparatus, and uniformity cannot be attained. It is perfectly possible to make these minute measurements. As a shop practice I would not advise it, because it is likely to delay output but, from the standpoint of its physical effect upon our minds in thinking mechanically, it is of very great benefit. In small measurements, then, we can measure 0.00000005 in.

While the mechanic has been measuring so minutely, others have been measuring large distances. In the way of velocities, automobiles in the early days traveled 25 to 30 m.p.h.; then they came to the 60-m.p.h. period; and then to 75 or 80 m.p.h. I heard recently that an automobile had been driven 155 m.p.h. But in a prospective airplane race in France this year those that cannot fly more than 200 m.p.h. will be eliminated. Projectiles reach 3000 ft. per sec., which is roughly 30 miles per min., but the astronomers sneer at these speeds; they deal with the velocity of light, which is 186,000 miles per sec. They know that accurately or they could not predict eclipses for years in advance. Light requires about 8.25 min. to travel the 93,000,000 miles between the sun and the earth, and astronomers tell us that the distances to the fixed stars, such as Polaris, are measured in another figure called the light year, which is 6,000 billion miles, and that the nearest fixed star is about twenty-one light years distant, or 126,000 billion miles.

Ultimate Structure of Matter

Why is the measurement of such distances of interest to automotive engineers? Because we are more concerned than at any previous time with the ultimate nature of matter. In the laboratories men are studying the ultimate nature of matter because there are problems involved which are very much nearer to the automotive industry than we think. We are beginning to conclude that a solar system such as ours, or any of the other solar systems many times larger, represents the physical structure of an atom; that the sun with its planets represents physically exactly what the atom is, with its positive nucleus and its negative electrons. We care about how an atom is put together, because this is perhaps most fundamental in helping us to solve the great problem of our fuel supply. We know more today about the ultimate structure of matter than we have ever known. Our

[1]President, Dayton Engineering Laboratories Co., Dayton, Ohio.

chemistry is about to be rewritten. The internal-combustion engine is a piece of chemical apparatus. We have never before so considered it. It has always been regarded as a piece of mechanical work, but it is a piece of mechanical work only insofar as it consists of physical parts. Its real function is chemical rather than mechanical.

A man named Mosler, in England, studied matter by X-ray spectroscopic work. His theory was based upon the entirely new conception that the smallest atom consists of one positive nucleus with a unit positive charge, and one negative electron; and that this combination represents hydrogen gas. His next conception was that a positive nucleus with two positive charges and two planetary negative electrons constitutes helium, and so on, each atom progressing above the other in one additional positive and one additional negative charge, so that the only difference in matter is a difference in the intensity of the positive charge on this nucleus, or sun, and the number of negative electron planets surrounding it, the distances between them being commensurate with the distances between the earth and the sun.

We are within reach of the time when we can break molecules into other forms of matter. Imagine a positive center with eight charges and eight negative electrons, and that it can be divided by a blow. We would at once get two pieces of four each, but they would have changed in nature and be entirely different types of matter. That is exactly what is observed in radium, which has a molecule so large that it breaks down of its own weight, so to speak, and it is constantly running down into various other forms of matter, finally terminating as lead, according to the latest theory. So that all matter that we deal with today is absolutely the same and made up in exactly the same way, but in different combinations. Such a system, or a knowledge of such a system, is essential to understand thoroughly such matters as plant growth. Just why a plant should grow when the sunlight shines on it is a mystery, but we must answer questions of that kind if we are to solve the real problems we have. Only in proportion as we are able to measure accurately are we able to advance constructively in engineering. Many of the great problems we have before us today are not commercial but those of measurement. It is necessary to measure the thing that is causing trouble. One of the great problems we have had in the fuel industry was to know what the problem is, to measure it so that we could attempt to solve it.

The Fuel Problem

We have about 6,000,000 automobile engines, including all types of internal-combustion engine used in transportation. This country ought to produce from 2,500,000 to 3,000,000 more this year. At present we have 2 gal. of gasoline per car per day. In other words, we are producing about 15,000,000 gal. of engine fuel per day. If we put it in 50 per cent more automobiles next year, we reduce the amount of fuel per car, which will increase the demand and the price. We have always had an abiding faith that American engineering and scientific work would meet any demand which would be placed upon it commercially, but for the first time in history we face a fundamental problem such as the limitation of one of our natural resources. We really have two natural resources whose limitations are being approached at present, the paper and the fuel industries. We are not in any immediate danger of having to stop running our automobiles, but we must get a perspective of what this fuel situation is, because it is only by so doing that the solution of the problem can be reached.

Science has made its great advances by the use of power external to man, whether through the use of animals or by other means. Therefore, the internal-combustion engine has come into our lives in such a way that we hardly recognize its tremendous influence. It is the first time in history that mankind has had a power unit of considerable size which can be manipulated at will, and which is almost wholly reliable, as evidenced by the large number of people who use it. That is a tremendous fact. We can get a perspective of what it means in everyday life by taking a backward glance to see what it meant during the war. The internal-combustion engine was a submarine, a submarine chaser, a tank, the motor transport, the airplane, the truck, the tractor, everything practically. It was the motive power of the war. We have been told that the thing that upset the German strategic plans was the fact that the Allies were able to move troops so much faster than the Germans believed possible. Through such reflection we can begin to see to what extent the internal-combustion engine has entered into the progress and development of civilization. It has entered just as much into our normal everyday progress as it did in the war, but it has come about so gradually and so naturally that we hardly recognize it. Today the automotive industry is almost as essential an industry as the bread industry. It is basic because it is today the most fundamental type of transportation the world has ever had, and when we recognize to what extent transportation is fundamental, we can realize why it requires analysis.

The curves of fuel production with relation to engine production show that the engine-production curve comes below the fuel-production curve for the first five or ten years, because gasoline was rather a drug on the market in the early days; then it crosses. One of two things will happen. The fuel-production curve will turn up, or the engine-production curve will turn down. There is no argument about it. Human needs demand that the fuel-production curve be turned up and the oil producer says that it cannot be done. That is the situation.

Let us see whether we can or cannot change it. From 1918 and 1919 statistics, the amount of gasoline produced in comparison with that of crude oil was something like 20 to 25 per cent of the crude oil pumped; that is, about 25 per cent of each barrel of crude oil finally became gasoline. About 8 to 10 per cent is kerosene. Then there is 50 per cent in which is gas and fuel oil, and a residue from which we get lubricating oil, paraffin, carbon, etc. The table of kerosene production for the last fifteen years shows that the demand for kerosene has been almost a straight line across the curve sheet. Therefore, kerosene production is a fairly fixed thing. We know that gasoline is creeping up gradually. Ninety-five per cent of the country's demand for kerosene oil is for its lights. Out in the country practically all lighting is done by kerosene lamps. China and Japan depend upon kerosene for lights. I mention this to show that there is a portion of this crude oil which must be reserved for kerosene or its price will run parallel with that of gasoline, because it is just as essential.

The limits on that fraction which we call kerosene are more rigid than the limits on gasoline. Otherwise we would not have gasoline, because gasoline today is a miscellaneous thing, a general term for almost anything. So, after utilizing 25 per cent for gasoline, we must skip the 8 to 10 per cent which represents kerosene and enter

the gas and fuel oil section, to get material with which to increase the amount of engine fuel. That is being done by taking this gas and fuel oil and "cracking" it, as it is termed. The simplest combination is that of carbon and hydrogen, one atom of carbon and four of hydrogen representing natural or marsh gas. The gas consists of two atoms of carbon combined with one of hydrogen, and these chains build up so that, in the heavier materials, the number of carbon atoms in a molecule is considerable and they are fairly heavy. If we heat them just right we can crack them; one fraction becomes gasoline and the others carbon and hydrogen. In the ordinary cracking process about 33 1/3 per cent of the total amount cracked becomes engine fuel, but this must be blended with normal fuel because it is an unsaturated compound. It contains another large molecule which tars up the intake valves. Our fuel today contains about 8 per cent of unsaturated compounds.

Ordinarily, we say that gasoline is a distillate of petroleum but, in the last analysis, petroleum is nothing but a liquid form of sunshine that was stored up ages ago. This country then had a luxurious growth of vegetation; it became covered and the natural distillates formed as crude oil. We drilled down and pumped it out, and that constitutes the oil industry of today; but every gallon of gasoline represents liquid sunshine. Alcohol as a fuel differs from kerosene in that it is last summer's sunshine instead of being the sunshine of past ages. A stalk of corn weighs from 2200 to 2500 times more than the initial grain of corn which was planted. That stalk of corn can be burned and a considerable amount of heat is liberated, but there is a residue of about 5 per cent of ash. Or, if the cornstalk is distilled into alcohol, the alcohol represents, in the heat it gives off, just as much heat as that stalk of corn when growing took from the sun. If only 5 per cent of that stalk of corn came from the earth, where did the other 95 per cent come from? The sunlight, by virtue of the water in the soil, forms carbohydrates and builds up the fabric of the stalk of corn. That whole stalk of corn is the final representation of the solar energy taken from the invisible atmosphere. The alcohol represents the solar work of putting those chemicals together.

Imagine a 6-in. snowfall, that the sun begins to shine brightly and that in 3 hr. the snow has melted. Then take a slide-rule and compute how many gallons of gasoline would be required to melt that amount of snow in 3 hr. This will give a tangible representation of what solar energy is. The sunshine falling on 1 sq. mile of the Sahara Desert is capable of running all the machinery in a large city. We must get back to such things and utilize them direct; that is one of the great scientific problems which is being studied along with the development of the automotive industry and we will eventually solve it. This may come about by means of alcohol or in some other way, but this is the real problem, and that is why we are so much interested in the ultimate structure of matter.

Science as Applied to Fuel

It would be possible today to increase our fuel supplies materially if it were not that the lower-gravity fuels cause pounding in the engine. This has been generally termed carbon knock. Many have thought that this is due to premature ignition. It is not; it is simply a change in the fuel molecules. Imagine a glass tube filled with an explosive gas at atmospheric temperature, and that we light the gas at the near end with a match. The flame will burn blue up to a certain point, then white, and at an intense white heat at the far end. Just at the point where the flame starts to burn blue, the tube will be clear; and where it begins to burn white, there will be a darkening due to the deposition of carbon. A critical temperature is reached at which the fuel molecules break down and in breaking down they give up hydrogen, and the rate of combustion goes up about eight or nine times faster than the normal combustion, which produces a peak.

An engine runs better after the carbon deposit in the cylinder has been removed because the ability of the cylinder to extract the heat units has thus been facilitated. A carbon deposit acts as a blanket around the inside of the cylinder, so that the temperature rises and the molecules break down. Very interesting photographic studies have proved that this occurs. To overcome it we lower the compression of the engine. When we do that we decrease the efficiency. It is possible to put into the fuel certain compounds which will prevent the breaking down of the fuel molecules. The compression of the engine can then be increased and there will be no knock, even if the cylinders are badly carbonized. The chemical and fuel industries should be sufficiently interested to make and put those compounds into the fuel. That is possible. In other words, we can today transfer in our distillation 50 per cent of the crude oil right over into the fuel, and put it into automobile engines with something which will prevent its molecular distortion. We could get better results with that 50 per cent of crude oil than we are getting with the present normal gasoline under normal conditions. I do not know whether we will be able to persuade the producers to go to the necessary expenditure, but it can be done at present, at least as an intermediary step, until we can produce fuels by an entirely different method. Carbon knock is entirely a function of the fuel. On almost all low-gravity fuels we add heat and that increases the knock. A single-cylinder engine run on kerosene at 85 per cent compression will knock, with normal air, but with the air at 10 to 20 deg. below zero the engine will run smoothly and develop its full power with kerosene, on high compression. At present, we heat the fuel before we introduce it; we raise the temperature about as high as we can and then drop the compression to compensate for this. We have confused the two factors in the great problem of the carbonization of fuel; one is a matter of fuel distribution and the other its chemistry. So, to get fuel distribution we try to vaporize it by heat, and this is exactly the wrong thing chemically. The single-cylinder engine already mentioned will run on kerosene as long as desired without any carbonization inside of the cylinder, because the essential for the formation of carbon, which is the breaking down of the molecules, has been removed.

We have analyzed many samples of carbon. About 90 per cent are very heavy hydrocarbons, 5 per cent are of a hydrogen-oxygen-carbon content and 4 or 5 per cent are precipitated lampblack. That 5 per cent of oxygen-hydrogen-carbon compound cements the other constituents to the cylinder walls. Something is required to dissolve it. It is of an acid nature; therefore many organic alkalies will act upon it, analine will dissolve 95 per cent. It is possible today to run engines on fuel heavier than kerosene, and to run them indefinitely and guarantee that there will never be any carbon deposit. We need not worry if we cannot persuade the commercial element to be discontented with what they have. The inertia of large organizations is considerable, and consequently we

may be obliged to hammer hard before we get them to move. I believe that future development will solve this problem. This does not mean that fuel will be cheaper than at present, but it will prevent it from going higher.

Aviation

Several years hence the aircraft industry will be a big business; it is in its infancy, but it is developing. It is a real institution. A means of transportation which is from three to five times faster than any other is a utility; it is such a great utility that we do not at first appreciate it.

I made only two railroad trips last year; I flew more than 15,000 miles. I was not out joy-riding; I was just at one place and wanted to go somewhere else, and I traveled in an airplane. Indianapolis is 110 miles from Dayton. To drive there in an automobile requires about 3½ hr.; on the fastest railroad train the trip occupies 3 hr. We flew from Dayton to Indianapolis in 50 min. We had lunch there and returned home within 3 hr. Detroit is about 225 miles from Dayton. We can have an early breakfast, fly over to Detroit, spend the day there and fly back for dinner; 1 hr. and 50 min. flying time each way. Columbus is about 70 miles from Dayton. It only requires 35 min. to fly over there. Two years ago, in winter, we flew from Dayton to Washington by way of New York, 560 miles. We made the flight to Mineola in 4 hr. and 10 min. We repeated that trip many times, and found out some interesting things. If the wind blows in one direction at one place, it must blow in another direction at some other place. We have been able to find a Dayton-New York wind, and when we flew a mile higher we found a New York-Dayton wind.

The aircraft industry does not advance faster because more people do not use it. The cost is too great. We have insufficient landing fields and many other needs, but the industry is here, and it will become a fundamental industry. The economic side of it is so fundamental and the commercial side is so tremendous that commercial organizations should awake to the fact that to reap commercial success they must contribute something to fundamental research problems.

Manufacturing Possibilities

This past war was the greatest thing that ever came to America, so far as causing an awakening is concerned. We could pay every cent that this war cost us within the next twenty-five years, if we made use of the things we discovered during the war. We have learned how to make cheese in this country, because of the war. They formerly told us that we could not make roller bearings over here; we could not, but we can make them now. They told us that we could not make optical glass, but now we can.

I inspected the European automobile industry last fall. We used to go over there to get the latest styles in automobiles. There was hardly a country that was not trying to copy some America-made article, and yet they said we do not know how to make an automobile.

No country in the world knows this business from a production standpoint better than America, but the rest of the world will not believe it. I tried to tell them how we do things over here, but they will not believe that we can make interchangeable parts as we do. They lack material and yet they start out with a billet of steel which weighs 960 lb., put it in a lathe and turn it down until finally they get a crankshaft that weighs 125 lb. When they are told that this is terrible from the standpoint of waste of material alone, they say they cannot make a better crankshaft and, if it is the best that can be made, they do not care what it costs.

The automobile industry is a fundamental one. From every angle it is in an undeveloped state, but I know of no business that has such great possibilities.

The Discussion

Mr. Lyman:—What causes the so-called gasoline knock, which generally comes from an excess or rich mixture, even when it is cold?

C. F. Kettering:—We have had the idea that the specific gravity of the fuel must be of a certain value. When the specific gravity is high, the volatile fuel molecules are small; and when the specific gravity is low they are large. So, to start an engine in winter the choker must be used. To get enough distribution to fire the engine, there must be an excess of present-day fuel to heat it up sufficiently to volatilize the remainder. Most people leave the choker on and this excess goes down to the piston-rings and into the crankcase.

Joseph A. Steinmetz:—Regarding the airplane proposition, in city planning, landing fields for airplanes and water-front areas for landing flying-boats or hydroplanes should be provided. At a meeting this winter, in Philadelphia, of the local branch of the American Institute of Architects, the policy was endorsed to give to city people throughout the United States the necessary inspiration in city planning and building, so that such fields can be laid down, at least on the map. It may be five, twenty-five or fifty years in working out to its accomplishment, but I know that many definite efforts are being made to put landing fields in the United States. In the State of Pennsylvania they have laid down over thirty. Great fields at least 1 mile square should be planned, to prepare for this wonderful development in which we all have faith.

Mr. Lyman:—Why does the Government continue to use the airplane for carrying mail? It certainly is not swift; it does not start from anywhere or land anywhere. The automobile must finish the trip, and some good men are getting killed every month. I think that business men do not use it, because it is slower than the railroad; so why continue?

Mr. Steinmetz:—You are misinformed. It is the proper thing to do; it requires splendid courage; it represents a definite national expression of a conviction that we all have of such a necessity. It may be a bad test of speed to fly from Philadelphia to New York, landing at Bustleton and on Long Island, and then using a motor truck. I grant that that is not a satisfactory result; an express train would beat it, but it emphasizes the thought that airplane landing places must be built in the civic centers.

Flights are being made regularly from London to Paris, over tempestuous seas. Sometimes one must wait a day to cross the English Channel, and letters are sometimes 30 hr. in reaching Paris from London, whereas, by airplane, 3 and 4-hr. deliveries are being made today. The great Norwegian air express from the coast of England to Norway is expected to carry letters over in a few hours that have required days to get over. The flights from Algeria to the French coast are made in a minimum of time. Competition between our airplane mail and train mail is not evident at the moment, but it will come, undoubtedly. It was a brave, splendid, heroic and proper thing to expend Government effort in the direction of aviation and its development, so that the

public would see that out of our war-time effort would come the great peace-time commercial application of the airplane. If it had cost $100 per letter, it would have been justifiable; but even now, according to the latest reports, the 2-cent air-mail letter rate makes money for the post office. It is terrible when an airplane goes down and a man is killed; yet that does not deter the onward march of aviation. Mr. Kettering spoke in terms of "light years"; we must look forward in terms of light years.

MR. KETTERING:—Fewer people are killed in aircraft travel per thousand miles than in perhaps any other method of traveling. It is marvelous. I know of no safer way to travel. To make any new thing a success money must be invested in research work and everything else. We do not yet know this airplane business. One need only fly for a few months to realize that the airplane is developed to about the same point as if we had ships with absolutely no paraphernalia of navigation. We have machines which fly, but the great paraphernalia of aerial navigation is not in existence. The only way we will bring it into existence is to try to do something; to find out what we can do and then do it. And that is why it is right to continue the air mails. That is the reason I believe in them. It is fundamentally correct in principle.

MR. BILLINGS:—Mr. Kettering explained that the cause of gasoline knock is the breaking up of the large molecules when the heat reaches a certain intensity. I should think that the molecules would have to break up to burn. I would appreciate a further explanation.

MR. KETTERING:—Any molecule whatever represents a certain energy; it has a certain amount of energy of combination. For instance, with a molecule of water, to pull the oxygen and hydrogen apart a certain definite amount of energy must be supplied to that molecule. We can accomplish this by electrolysis or by heat. In the case of gasoline, when the temperature is raised to 750 deg., enough energy is supplied by the explosive energy of that gas to cause the molecules to come apart. The difference between the burning in one case and the burning in the other is that whenever the temperature reaches a certain point by virtue of the specific heat, the molecule is absorbed; the carbon and hydrogen are separated, producing free carbon and free hydrogen. The rate of combustion of the hydrogen is about six or seven times faster than that of the carbon, and it produces a very great impact. We have taken many curves by making such explosions in glass bowls. Whenever the temperature reaches the point where the molecule is absorbed, it comes apart; the heavier the molecule the easier it comes apart. By adding some compound to the fuel, we introduce a molecule that breaks down more easily than the fuel molecule and, when the wave of combustion starts, it breaks that molecule down first and that absorbs the excess energy. In normal burning, the specific heat of those gases is so small that a few British thermal units plus or minus make a terrific difference in the temperature.

FRANK A. DICKMAN:—What are the relative commercial merits of a dirigible and an airplane, and the relative commercial merits of the Zeppelin and the British dirigible?

MR. KETTERING:—For very long across-water flight, I prefer a dirigible. I do not know the details of their construction. I think it is a matter of cost. There are many considerations involved as to the relative merits of the English and German dirigible. From a commercial standpoint the airplane business must be carried on in one of two ways, either for private or for commercial use. For passenger carrying we have not secured sufficient speed, because when we build a large machine it cuts down speed. The engines are very expensive. I do not look for much development as long as engines cost $20 per hp. If we had an airplane today with 80 to 100 hp. that would carry two or three persons at a speed of 100 m.p.h. and sell for $3,000, we could do $5,000,000 worth of business next year. So long as we design engines and do not care what they cost, we will not get inexpensive production. We must require certain things and that they must not cost more than a certain amount; then we will Americanize the airplane. It is a question of cost and of simplicity of construction.

JOHN D. GILL:—Regarding the matter of the dilution of oil in the crankcase, about how much gasoline of the grade used by the Navy would go down into the crankcase in a 500-mile trip?

MR. KETTERING:—That depends altogether upon the percentage of load. With the engine running at high temperature, practically none would go down; at low loads, in cold weather, a considerable amount would go down. Many things influence the matter, such as the fit of the piston, what percentage of the time the engine runs, the section of the piston, etc. It is very difficult to make a general statement. It depends upon the temperature, the particular grade of gasoline used, the brand of lubricating oil, piston fit and the kind of fuel mixture. This effect first developed on physicians' cars and the closed cars. I have actually seen 3 gal. of stuff that had passed the pistons taken out of motor cars within a month. It is a common thing; it happened on closed cars because the closed cars were used by people who did not drive fast and made many stops. Physicians have greater trouble because they make many short runs and numerous stops.

R. D. LEONARD:—There seems to be nothing more talked about among the automobile interests than the elimination of crankcase oil; yet there is much indefinite information. We hear in one case that a man runs 500 miles and will have as much as 33 per cent of light material. Another man will say that on a similar run he has probably not more than 2 or 3 per cent. Have any tests been made which would indicate what is a fair or reasonable percentage to expect?

MR. KETTERING:—We have had a refrigerating room for years in which we have run these cold tests all the year. There is no way that we can determine it. It depends altogether upon the temperature of the engine. If that temperature increases up to the temperature of the lubricating oil, the light materials will go up; and if you run slowly they will go down. I can take the same engine that produced 33 per cent of light material and drive over the same 500 miles; at the end of the trip I will have 110 per cent plus; because I can boil it all out within 500 miles. It is a temperature relationship.

MR. LEONARD:—But do you not regard it as a problem of the automobile today?

MR. KETTERING:—It is the biggest problem we have.

MR. LEONARD:—We had the same difficulty four or five years ago.

MR. KETTERING:—That was about the time the quality of gasoline began to drop, about 1914. I made the following very spectacular demonstration to an automobile manufacturer in Detroit, when high-volatility gasoline was obtainable. They would do all their experimenting with that and then wonder why they had trouble in the field. We took a quart can of ordinary gasoline to the roof of a factory building in Detroit, when the temperature was

10 deg. below zero; the next morning I lighted a match and put it in the gasoline and it put the match out.

MR. LEONARD:—We have the same grade of gasoline today.

MR. KETTERING:—We have the same grade, but that was not the prevailing grade at that time. We have been two years behind our fuel conditions in engine design. Instead of trying this year's engine on two-years-from-now fuel, we have done the reverse. If we could design engines to run on the fuel which could be obtained a year or two later, it would help the situation greatly.

W. M. NEWKIRK:—Regarding the addition of certain chemical elements that will improve the action of the gasoline, must those compounds be added at the refinery?

MR. KETTERING:—We can add a small amount of xylidin or of aniline to the fuel and produce interesting results. In Major Schroeder's great-altitude flight at Dayton, the first time he went up with his supercharger on he could reach only a height of 32,000 ft. The reason his engine overheated at 32,000 ft. was that he had to raise the compression about 6½ lb. with his supercharger and, as indicated by the volumeter on the Liberty engine, the temperature was up to about 50 deg. cent. When he made the second flight we put in 2 per cent of xylidin, and he was able to reach a height of 36,000 ft. The internal-combustion engine is more of a chemical machine than a mechanical one. All we did was to change the chemistry in the second flight.

A MEMBER:—Why could not some enterprising person, using gasoline as a base, put some of these compounds into it, give it a name and put it on the market?

MR. KETTERING:—The problem of gasoline distribution is one of the most complex ones we have today. If one should attend an oil convention, especially a dealers' oil convention, and see the problems of distribution caused by trying to handle two grades of kerosene and gasoline, the great difficulty of trying to add a third fuel would be apparent. It could be done.

MR. STEINMETZ:—Recently, I obtained some pellets that looked like moth-balls; they were a brilliant green. They were said to increase the efficiency of the engine. We shall eventually be able to buy some such compound at a small price, guaranteed to raise the efficiency of present gasoline by a large percentage.

MR. KETTERING:—That sort of pellet has been used all over the world. Napthalene, if it is introduced in the right way and the walls of the cylinder are wet with it, has a consolidating action on the carbon, but so far as adding anything to the value of the fuel is concerned, it does so only insofar as it dissolves the carbon deposit on the cylinder wall.

W. L. DEMPSEY:—Is it not a fact that the only time there is any dilution in the crankcase is at low and medium-throttle positions, because the compression and the temperature are low, and condensation takes place? A mule never kicks while pulling and a spark-plug will never foul while pulling.

MR. KETTERING:—If the engine is kept hot, and right on the throttle, that is true.

MR. DEMPSEY:—The remedy then is uniform compression at all throttle positions?

MR. KETTERING:—Yes, if one gets the compression up it is all right.

HUBERT C. VERHEY:—Is an attempt to increase the work of the gasoline now being used for internal-combustion engines the only step that should be taken in endeavoring to solve the present fuel problem? If we acknowledge that 50 per cent of the original crude oil as it comes from the ground can be used in other than automobile engines, it seems that the automotive industry particularly should try to utilize that amount of crude oil, although we have found that such utilization is not easy. There are engines, such as the Diesel engine, which use the heavier grades of fuel oil, sprayed into the cylinder at a point where extreme peak loads are not so likely to occur as in a gasoline engine, because the compression is carried up to practically the upper dead-center, after which the oil is admitted under pressure, so that we are handling that heavier stuff satisfactorily. To apply the same principle to automobile engines and use heavy oil we would need to make use of a pump to force the fuel into the cylinder, where it must be well distributed, which is generally done by the introduction of compressed air. I see no reason why that principle could not be applied to automobile engines, although I know that, owing to the very small quantity of fuel oil needed for each working stroke, thus far no satisfactory solution has been found. It therefore seems desirable to invite all automotive engineers to utilize their experience toward a solution of that problem. We have not been able to make a pump small enough to handle the very small amount of fuel oil required for each working cylinder. The distribution of the fuel does not give trouble in the larger heavy-oil engines. It is done by injection, in combination with compressed air or by the so-called solid-injection system, as it has been proved that it is possible to introduce the heavy fuel directly into the cylinder by forcing it in under a high pressure varying from 4000 to 5000 lb. per sq. in. This system as it stands today seems to have mechanical weaknesses and tends to give more undesired carbon formation. However, the principle is right. With small engines such as are required by the automotive industry all these facts must be considered by engineers, and it seems to me that we could do these things by close cooperation. What would happen in case it made no difference whether we were to run engines on gasoline or the heavier oils? Can Mr. Kettering predict what that would mean for the market or what change would result?

MR. KETTERING:—If such an engine were a developed machine and had been proved successful, the automotive industry would accept it immediately, and there would be money in it for the man that proves it efficient. Very serious efforts are being made in this direction. There is not a single type of engine that at the present time is not undergoing extensive consideration in some one of the numerous laboratories maintained by the prominent automobile builders.

EFFECT OF ALTITUDE ON RADIATOR PERFORMANCE

THE effect on the performance of aircraft radiators of changes in atmospheric conditions at altitudes is discussed in Report No. 62 of the National Advisory Committee for Aeronautics, Washington. A method is developed for estimating the performance at any altitude from the performance at the ground with probable atmospheric conditions. Meteorological data are included, from which the atmospheric conditions at different altitudes can be estimated, and the method is illustrated by its application to two types of radiators. The degree to which an aircraft radiator should be shuttered to improve its performance at various altitudes is also considered briefly.

Preignition and Spark-Plugs

By STANWOOD W. SPARROW[1] (*Member*)

ANNUAL MEETING PAPER *Illustrated with* DRAWING

THE discussion of this paper and the author's reply were not available in time for publication in the May issue of THE JOURNAL with the comments on the other papers presented at the Annual Meeting of the Society. For the convenience of the members a brief abstract of the paper which was printed in the February issue of THE JOURNAL precedes the discussion.

ABSTRACT

THE author proposes to determine what features of spark-plug construction cause preignition and how this preignition manifests itself. To this end observed conditions on an Hispano-Suiza aviation engine following 4 hr. of an intended 6-hr. run are reported, with supplementary tests and observations. This resulted in experiments made to determine the cause of preignition, using spark-plugs constructed so that different features of their design were exaggerated. Illustrations of these plugs are shown and the results obtained from their tests are described. The different observed peculiarities are then stated, analyzed and compared with normal spark-plug performance. The experiments serve as a means of identification of special forms of preignition and as an indication of the abnormally high temperatures to which valves and combustion-chamber walls are thus subjected. They also serve as a basis for predicting the performance of a given design of spark-plug or for designing a spark-plug to meet known conditions.

THE DISCUSSION

THOMAS S. KEMBLE:—In 1915 the Curtiss VX engine was developed with a rather high compression-ratio for the sake of the advantages to be obtained at great altitudes. Inspection requirements, however, demanded full-throttle dynamometer tests of considerable duration and preignition developed. This was reduced to passable dimensions for dynamometer tests by reducing the compression somewhat and the air performance was very good for that period. Later, the volumetric efficiency was improved to such an extent that serious preignition again developed. This time repeated tests demonstrated that preignition occurred only in conjunction with leaky spark-plugs. The trouble was eliminated by using gas-tight plugs only. At that time gas-tight plugs were very difficult to obtain. Since then the situation has altered materially through the cooperation of spark-plug manufacturers and good plugs are easily obtainable. An interesting feature developed in that on at least three occasions a hole appeared in the aluminum intake manifold near one of the intake ports. This hole looked as if it had been caused by intense heat. We had been unable to get these engines to pop back through the carbureter intake without holding one of the intake valves well open. We therefore attempted to explain the manifold failure as being due to continuous popping back which failed to reach the carbureter intake. In view of Mr. Sparrow's observations through the intake manifold, I am convinced that our explanation was probably the correct one.

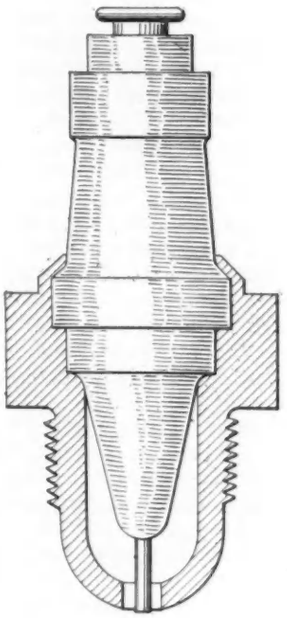

FIG. 1

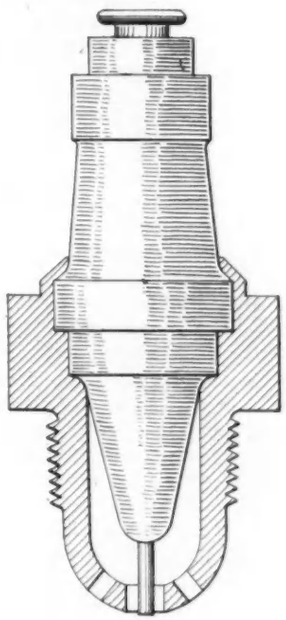

FIG. 2

R. CHAUVEAU:—The tests we made during the war on various types of engines confirmed entirely the statements made by Mr. Sparrow. I will add an assumed explanation of the causes of the preignition. In the spark-plug shown in Fig. 2 it is, to my mind, due to the fact that there is an opening between what I would call the inner chamber of the spark-plug and the cylinder. The volume of this chamber is several times larger than the opening. During the explosion the pressure in the chamber is raised to the same degree as the pressure in the cylinder. This necessitates the passing of an amount of hot gases through the opening into the chamber. With these gases passing through a small opening alongside the electrode, it is natural to assume that they will transfer a certain amount of heat to the electrode itself, and this amount of heat is proportional to the speed and pressure of the gases.

The cooling of the center electrode is, in my opinion, effected mainly through the top of the electrode outside of the porcelain and only to a very small extent through incoming gases from the intake valve. That theory ex-

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plains why we have preignition on the plug shown in Fig. 2 and not with the plug shown in Fig. 1, as the opening of the chamber is not restricted to any large extent. This theory was confirmed by another type of plug, of which I submit a sketch. As shown in Fig. 1, it would consistently cause preignition. By drilling four holes, as shown in Fig. 2, in the shell, we would deflect a certain amount of the gases from the annular opening around the center electrode and eliminate the preignition. The plug shown in Fig. 3 in Mr. Sparrow's paper was claimed to cause preignition. This can be explained by the fact that while the opening is not restricted as much as in Fig. 2, at the same time the chamber in the shell has been increased 150 to 200 per cent, so that the proportion between these two remains about the same and, in addition, a larger area of the center electrode has been exposed. It is further proved in Figs. 5 and 6 that preignition is eliminated by increasing the opening to the chamber.

In conclusion, I would say that we have found the open-type plug the most satisfactory, and that the larger the center electrode is the less is the danger of preignition, provided the free end which extends beyond the porcelain inside the shell is short.

Another advantage in running the electrode as cool as possible, accomplished by the use of a heavy electrode, is the fact that it will cut down the leakage of the high-tension current and provide a more concentrated spark. The ground electrode is not likely to cause preignition, in conformity with Mr. Sparrow's statement. It is preferable always to use the single-ground electrode to concentrate the high-tension energy in one strong spark rather than distribute it among a number of weaker sparks. The single-ground electrode also cuts down electrical leakage.

In designing spark-plugs for aviation engines, I have found, however, that the engineer is limited as long as he has to use the materials now available for spark-plugs, and that it is impossible on this account to design one plug that will be universally good for all types of engines. In fact, a new engine and an older one of the same make, type and construction, require as a rule differently designed plugs, as the spark-plug in a new engine must be designed for high temperatures and a small amount of oil, whereas in an old engine the spark-plug must be designed for lower temperatures but for an excess of oil. It is only in rare cases that these two features can be combined into one spark-plug.

S. W. SPARROW:—Spark-plug leakage would be very apt to produce the preignition troubles described by Mr. Kemble. I think his explanation as to the cause of the hole in the intake manifold is undoubtedly correct. It is a pleasure to know that Mr. Chauveau's experience confirms so completely the results obtained in the tests at the Bureau of Standards. His explanation of the cause of the heating of the center electrode is of decided interest. I feel sure, however, that when an electrode is exposed to the incoming gases, much of its cooling is due to the heat taken from the electrode to vaporize the liquid fuel or oil that is thrown against it.

FOG-BOUND AIRPLANES GUIDED BY WIRELESS

IT has been known for some years past that stronger wireless signals could be received when the top and bottom wires of a rectangular aerial were pointed in a direct line toward the sending station, whereas the signals were very much weaker when the aerial was placed so that the top and bottom wires were at right angles, or broadside on to the sending station. At intermediate positions of the rectangle the signals varied in strength from practically nothing, when at right angles, to the maximum strength when directional to the sending station.

The rapid turning about of large aerials in that manner is not practicable; therefore the Marconi Company erects two independent triangular or rectangular aerials fixed with their planes at right angles, and connects them to the direction-finder box, which may be said to reproduce the external conditions in a small space. Inside the box there are two fixed "field" coils, mounted in planes at right angles and connected to the aerial wires. Within these fixed coils is a rotatable "search" coil. This portion of the apparatus combines the signals received on the two aerials, so that the movable "search" coil is influenced by them when in a plane directed towards the sending station, but is unaffected when it occupies a position in a plane that is located at right angles to that direction.

The dial of the finder is calibrated from 0 deg. to 360 deg., and is arranged so that the direction of the incoming signals is due north when the direction pointer is at 0 deg. When signals have been obtained, the apparatus is tuned to the proper wave-length as in ordinary wireless reception. By rotating the handle of the direction finder, the strength of the signals in the telephone headgear will be heard to vary. The maximum strength will be heard at points diametrically opposite on the scale, and between these positions the sound gradually decreases until at two other opposite points, midway between the maximum positions, there is silence.

Since at the present time it is not possible for one direction-finding station to determine from the received signals alone the *distance* of their origin, but only their *direction*, it is necessary to make use of two or more stations separated by a considerable distance. Such stations having obtained the directions of the transmitting station, in this case, the airplane, it is only necessary for the control station to plot these directions on the map, when the point of intersection will give the position required.—*Illustrated London News.*

TESTING A HISPANO-SUIZA ENGINE

IN testing a 300-hp. Hispano-Suiza aviation engine by the engineering division of the Air Service at McCook Field, Dayton, Ohio, it has been found that at increasing altitudes the power drops much faster than the air density or pressure. The specific fuel consumption increases gradually up to the 15,000-ft. altitude, above which point it becomes excessively high, due partially to an inadequate mixture control and a lowered mechanical efficiency. At the 15,000-ft. altitude, the friction horsepower is about 18 per cent lower than at sea level.

On propeller load operation, the specific fuel consumption at 5000-ft. altitude is apparently as good as at sea level; at 10,000-ft. altitude it is from 10 to 15 per cent greater at various speeds; at 15,000-ft. altitude it is from 15 to 35 per cent greater at various speeds than at 5000-ft. altitude.

At sea level, the horsepower varies inversely as the carbureter air temperature, but not nearly in proportion to the absolute temperatures. The specific fuel consumption increases considerably with the lower temperatures. At 15,000-ft. altitude, the same general tendency obtains, without as wide a variation in the magnitudes as at sea level.—Air Service News Letter.

Addresses at the Truck and Tractor Dinner

THE speakers at the dinner held in connection with the Truck and Tractor Meeting of the Society at Chicago on Jan. 28 included, in addition to Fred L. Glover who acted as toastmaster, Major-General Leonard A. Wood, U. S. A., commanding the Central Department; E. J. Gittins, of the National Implement and Vehicle Association, and Major-General C. C. Williams, U. S. A., chief of ordnance. The addresses which were enthusiastically received are given, substantially in full, on the following pages.

ADDRESS OF MAJOR-GENERAL LEONARD A. WOOD

I HAVE a very great appreciation of what the automotive engineering profession is doing. I remember very well being with the French and German armies when all Europe was on the verge of the great war which followed, and I was particularly struck with the want of any kind of motor transport. People were talking about it. We saw here and there some queer vehicles, but there was no motor transport to speak of. There were some traction trains, but they were hard to manage.

A year later we had what we called mass maneuvers. They were uncontrolled maneuvers covering some 300 or 400 miles. I borrowed twelve or fifteen motor trucks. This was looked upon as an experiment. But when we think what has happened in the past few years and what motor transport means today, we realize what the automotive engineers have done for transportation. I think none of us realizes what the automotive engineers will do for transportation. They are going ahead by leaps and bounds and there seems to be no limit to what they will do.

One thing must be done and that is to put over the good-roads program all through the country. We have been thinking and talking about a system of national highways. In some sections they are really under construction, but we ought to put all the influence we can behind the visions of those national highways which are so important, not only for the needs of peace but for the needs of possible war. Those hosts of lines of communication, those lines along our frontiers and the great connecting lines, when they are built and roads of proper construction are ready, our task will be larger than ever.

I hope the automotive engineers will continue their work in aviation; that is, on the engines for the various types of airplane. It seems to me that we are rather dropping back in that at a time when we ought to be going ahead and going ahead hard. We ought to keep up enough flying fields all over the country and try to push forward general training and development in aviation. No man can be an aviator long and we must always have additional aviators developing. We need the best possible type of engine. That type, I feel sure, the American automotive engineer will give us. I think we want to push that and keep it going.

I want to suggest and urge upon you that you do all you can to keep alive a reserve corps for the motor transport and a reserve corps in the various lines of the automotive engineering profession. Automotive engineers were simply invaluable to us in the great war and will be invaluable to us for the demands of peace. We want them to be ready to meet any possible emergency in the future. We must maintain the splendid motor-transport organization that was built up during the war; we have got to go ahead with it. We want to organize the automotive part of our national resources just as we organize any other. If we ever have any other great emergency, we should find a nation organized to a far greater strength than before as a result of the lessons of this war. The fighting line, the Army and Navy, might be compared to the edge of a heavy knife-blade. They are the cutting destructive force, but back of them is the great mass of steel which gives weight and rigidity to the edge, the organized resources of a nation, replacing the wastage of the edge and giving it weight to drive it home.

While that is true in war, it is also true in the pursuits of peace; in industry and the building up of commerce and trade. I think we have very severe competition ahead of us. The people in Europe have been tremendously knocked about; some of them, notably the Germans, are coming out very lean and light and ready for a keen commercial struggle. They have their financial difficulties and all that, but it is well to remember that they have learned to live without export and import. They have acquired a practical thrift habit and their industries, their shops and their factories are undisturbed. Competition will come. We must build up, not only in the automotive but in every other line, the organization that we need to carry on our part in the big world program. We must build up an intense American spirit, absolutely American; not selfish, not narrow, but American. Back of it we must have a national conscience, which will make America quickly responsive to any situation which demands our assistance, but we want it to act always as America, and to remember that the mandate which we will always accept cheerfully is the mandate which comes from the conscience of the American people. That is our mandate. We have a strong mandate now, abroad. It is that we, with the money and wealth that have come to us in this war, do our full share in alleviating the conditions of distress and suffering on the other side. There is a big problem over there, and we have a big moral responsibility. I am not talking now of armed forces in Europe, or of intermingling with and intruding into European politics. I am speaking of responding to that one mandate which comes more and more to all of us as the days go on, and that is the mandate to put these suffering people on their feet, with food, shelter and clothing. It will be a big proposition, but the bread thus thrown on the waters will come back to us in many ways. We can do it without in any way intermingling with their affairs.

I wish we had the same progressive forces throughout

the country as are represented by the Society of Automotive Engineers. I hope you will push forward the reserve idea for motor transport and do everything you can to standardize production. I also hope that you will put your best thought into the development of aviation, not necessarily for war, but for those commercial usages to which it will without doubt soon be devoted very largely.

ADDRESS OF E. J. GITTINS

I ASSURE you that I deem it a privilege to be in this company. I will not presume to undertake to enlighten you on any of the technical questions of the industry, for I am not an engineer. Any discussion of agriculture must necessarily be based upon fundamentals. It is a fundamental business. It is the background, the foundation, of all human activity. Any people or nation that ignores this fact will not advance very far. The United States is primarily an agricultural country. The vast expanse of fertile land that we have is far in excess of the power that we have had available to till it properly. This has furnished the incentive for inventive development which has placed our country in a class by itself among all the nations of the world for producing crops with the minimum of human labor.

How we have advanced in this industry is illustrated in a paragraph of a little pamphlet issued by the Agricultural Publishers' Association, as follows:

> In 1885 the amount of human labor expended in growing an acre of corn was 183 hr.; today it is nineteen. In 1830 it required 66 hr. of human labor to grow an acre of oats; today it takes 6 hr. Sixty years ago the farmers cradled the wheat and hauled it by hand to the barn and then threshed it. For each bushel of wheat harvested, these operations required 183 min.; one man using the labor-saving machines now found on the farm can do the same work in 10 min. With a combined reaper and thresher, operated by steam or gasoline, and a gasoline tractor to plow and fit the land, less than 3 min. of human labor is required for producing a bushel of wheat.

While we have always had more land to till than we have had labor to till it properly, conditions have arisen in the last few years that have created an emergency, and reference to a few well-known facts will I think illustrate the truth of this statement. In the ten years prior to 1915 our immigration into this country was something more than 1,000,000 a year. In the last four years the immigration has been only about 200,000 and more people have been going out of the country than coming in. The population of the country in 1860 was about 31,000,000, of whom 5,000,000 lived in cities, less than 20 per cent. Even as late as 1880 80 per cent of our people lived on farms. Now the population is perhaps 105,000,000, with only about 30 per cent living upon farms. It is said that 8,000,000 people have moved from farms into the cities since 1900. Our increase in population since 1900 is more than 20 per cent, but our crop production has increased only about 10 per cent. I give these figures to call attention to the rapid change that has been going on in this country and leading up to the farm requirements of the present day. The effect of this great change in the relative city and country population is not only to curtail production of food products, but it is, in my opinion, one of the principal factors in the present high cost of living. That, in turn, is a principal factor in the present unrest throughout the world, an unrest that is even shaking the foundations of governments.

The progressive activities of American automotive engineers have met the situation in a remarkable degree, with the result that we now have hundreds of thousands of mechanical machines operating upon the farms as substitutes for human power. Perhaps the greatest and most arduous work of producing crops is the preparing of the soil for the seed. It is the tractor that has been developed to accomplish that work with the minimum of human labor. The tractor is not altogether a new departure, as some seem to think. Engines have been used on farms for fifty or sixty years, first as steam portable engines, then as steam traction engines. Steam traction engines were being used more and more for general farm purposes, but about the time they had been developed so that they were practical and being used generally, the internal-combustion engine was developed to a practical stage and applied in the place of steam power. Why did it take the place of steam power? Simply because it replaced more men. There is no piece of machinery anywhere, I believe, that is subjected to such continuous hard work and under such fearfully adverse conditions as farm machines, especially tractors that must work over the rough and dusty lands. I believe that most manufacturers do not fully appreciate this fact when first commencing to build their product, but it has been borne in upon them with the result that changes and improvements have been made continuously, until we now have practical machines. There are many things yet to be remedied. The industry is still in its infancy. Improvements are going on rapidly, although they are not so evident as formerly.

It seems to me that the question of shortage of human or mechanical power for the farm is so vital, so far-reaching, that it should enlist the attention and the assistance of even the Government. The evils, or the shortcomings, in the business have brought about regulatory legislation such as has been passed in Nebraska, and threaten to bring about more State legislation. This legislation should be welcomed, but it should be uniform in all States. That is the reason builders favor national rather than sectional regulation. The subject is of such importance, the question of production of crops is so far-reaching, that our national legislators should have personal interest in the question.

Farming is a hazardous business in many ways. There are many risks in it, more than in most other enterprises. The land must be tilled properly at the right season of the year. The crops must be taken off at the proper time and oftentimes very quickly to avoid serious losses. This means that the mechanical power which displaces the human power must be dependable to be available when required.

The one thought that I would like to leave with you is that we should strive, as engineers and manufacturers, to design and build so that farm power machinery will be dependable. We should also recognize the fact that most farm machinery is operated by inexperienced people. Hence it should be as near 100 per cent right as it is possible to build it.

ADDRESS OF MAJOR-GENERAL C. C. WILLIAMS

WE are now passing into a new era, into a time when we must really make plans and crystallize the experience we have had during the past war, so as to make it available for the next war, because, if there is one

sure thing ahead of us, a thing that is just as sure as death, it is that we are going to have another war.

We have now a general staff. It is organized for the purpose of studying world conditions, for making assumptions as to probable enemies and for working out plans of campaign both offensive and defensive. But when a plan of campaign, either offensive or defensive, has been made, only half of the work has been done. There is no use in raising an army of a million or several million men unless we can equip and sustain them in the field. If our experience in this war has taught us anything, it is that we should take the plans of campaign that are prepared by our general staff and turn them over to an industrial general staff, if you choose to call it so. This industrial staff can then develop the industrial plans that will be necessary in order that the industries of the country may be put in operation to produce with the least delay and the least friction, the material that is required to sustain the troops in the field.

In a way, this is the thought that is back of the Army's relations with this Society. You have been extremely valuable to us during the war. We want to maintain the contacts that we have made with you. We want you to know what the Army problems are, what they will be during the next war, or any war that our general staff may make plans for. We want your assistance in working out our problems of development, design and production.

The war that has just closed left us, of course, with many more unsolved problems than there were in the beginning; that is, so far as munitions are concerned. Mechanical warfare experienced a tremendous development; but no one can say that the surface is very much more than scratched. We want to keep in touch with you concerning the developments that we foresee and to get your assistance in the developmental work, which is one of the most important things we have.

I had the good fortune to attend your 1919 Summer Meeting and there told you that we hoped to do certain things in the matter of getting in touch with you. Some of those things have been done with happy results. Your Society has appointed a committee of your ablest engineers to work with us, to go over our problems with us and to help us out in our work. That is already started and the cooperation between the Society and the Ordnance Department is all that we can desire. We look forward to maintaining it in the future. It will require effort on the part of all of us to do so because we cannot, in all probability, put out many orders. Congress probably will not give us much money. We hope that there will be some. We hope that we will have a chance to put a large proportion of our appropriations into the industries, because it is only by manufacturing the things that we want that you may learn how to manufacture.

The man who is commanding troops has a great advantage over us in preparing. He can get his regiments, brigades, divisions, army corps and armies and can inaugurate maneuvers in which he tries out his various theories as to how troops can be managed. I know of no way in which you can so maneuver in manufacturing a 16-in. gun. The only way is to build it.

Insofar as I am personally concerned, I am opposed to the complete manufacture of ordnance material in the arsenals. Unfortunately, there is a stronger and stronger indication in that direction. Many of our appropriations come to us requiring that the work shall be done in the arsenals. The very best way, the best solution of the ordnance material manufacturing problem, in my opinion, is the German solution, in which every agency of the Government was at the service of firms like Krupp and Ehrhardt, so that a munitions industry was built up. Young men coming out of the German technical schools and universities could go to Krupp and other places and find a career of honor and profit. A large force of trained men was built up, factories were built; in fact, the munitions industry was a going concern. The value to the Germans of organizations like Krupp, when the German nation was called upon to make its great effort, cannot be overestimated. Unfortunately, that method cannot be followed in the United States. The very best we can do is to manufacture at Government arsenals, with all the encouragement that we are permitted to give to private industries.

It is a great pleasure for me and for the officers of the Ordnance Department to work with you. We hope that in the years to come this good relation will be maintained. We are sure that it will.

THE AERIAL CROSSING OF THE OCEAN

ONE great factor dominates the whole problem of ways of communication. It is "speed." It is not sufficient to have routes running in all directions and covering great distances; it is all-important for the actual motion to be as rapid as possible. The great influence of speed in the social organization of human activity is not always recognized sufficiently. For example, one can mention the fact that Napoleon in the last years of his power expressed some doubts as to the value of Stephenson's railroads. We must not be astonished if the entire extent of the influence of the speed factor is not realized by all, probably because it is too vast in its majesty and power. But some of us have within ourselves a feeling, more powerful than the conscious reason, which instinctively tells us what speed is. Great men and great peoples have always paid a worthy tribute to speed. A beautiful example is given by the development of the United States, where the social importance of the speed factor has been understood from the origin of the country.

Speed of transportation means acceleration of activity, increase of the people's efficiency, and, as a result, economy of time, with all its enormous consequences. Saving of time brings the necessary amount of leisure for meditation and personal improvement, which are the original sources of all progress in any line of endeavor.

Speed of transportation means also increase of human lifetime, which always was and is one of the burning desires of man, and hence one of his greatest felicities. Terrestrial routes have passed through different well-known stages of development and have now reached a high degree of perfection, in the sense of speed as well as in weight of material transported. Waterways unite only different parts of different continents, or, by rivers, give only a limited access within the continents. The conquest of the air, the marvelous realization of the end of the twentieth century, has finally given us the aerial way of communication, the first to be universal. We find ourselves now on the eve of the establishment of great universal aerial voyages, transoceanic as well as transcontinental.

The history of all mankind is merely the history of its fight against slavery by the forces of nature. Science is our powerful liberator; it teaches us how to use these forces for our own benefit.—Dr. George de Bothezat.

Motor-Bus Transportation

By G. A. GREEN[1] (*Member*)

SEMI-ANNUAL MEETING PAPER *Illustrated with* CHART

IN the design, manufacture, and operation of the motor bus, one must come into contact with practically every field of industry. This paper should be considered as an introduction, for the subject is so far reaching that one can at best here only touch lightly upon some of the more interesting aspects. The motor-bus industry is of very recent growth. It is, however, rapidly establishing itself in popular favor. Unquestionably, the so-called "jitney" is merely a forerunner. It is, however, fulfilling a useful purpose since it is creating a desire for real bus service. Trackless transportation has unquestionably come to stay and it is confidently anticipated that in the very near future the automotive industry will give this branch of its family something more than a name.

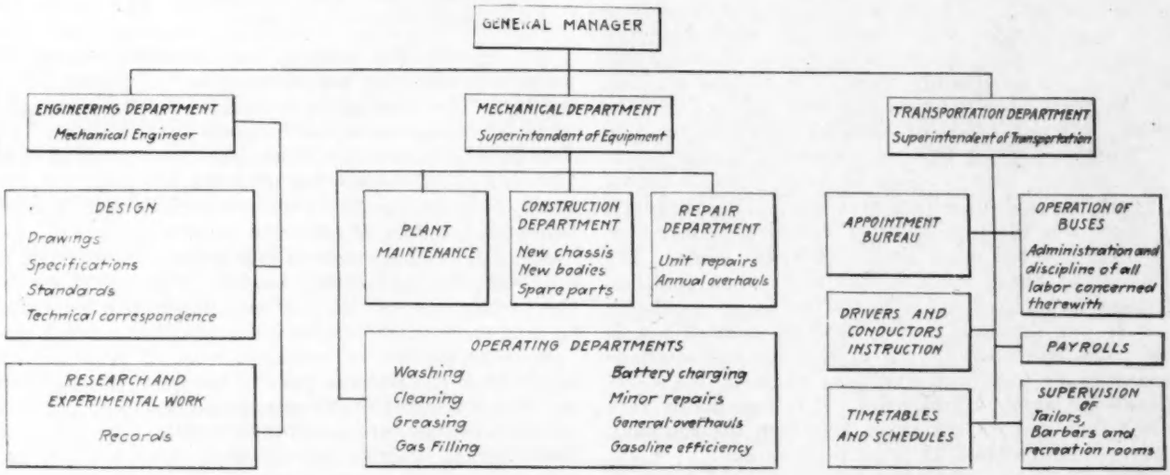
It is hoped that those who read this paper will not feel that too much space has been devoted to the Fifth Avenue Coach Co. I am expected to give my views on motor-bus operation, and since this company is the only successful one of any size in the United States, it necessarily follows that a rather lengthy description of the coach company's systems and methods must be given.

The three main divisions of the Fifth Avenue Coach Co. are the engineering, mechanical and transportation departments as shown in the accompanying organization chart. There are, of course, departments concerned with finance, auditing, purchasing, publicity, claims, etc., but these follow conventional lines and no further reference will be made to them.

ENGINEERING DEPARTMENT

At the head of the engineering department is the mechanical engineer. His duties and responsibilities are broadly outlined above. It is scarcely necessary to refer in detail to the duties of this department as it follows closely along conventional lines.

In this paper, space will not permit the question of design to be discussed in detail. It is hoped, however, that in the near future an occasion will present itself to review this most interesting subject. A rather general impression prevails that the average truck chassis can be successfully employed for motor-bus operation. We do not hold this view. There certainly are many instances where modified truck and touring-car chassis have been profitably employed for buses, but in such cases had the right type of vehicle been used much more economical, satisfactory, safe, comfortable and convenient operation would have obtained. Furthermore, where financial failures have occurred, many of these could undoubtedly have been avoided, assuming, of course, the employment of the right kind of vehicle. In my opinon, the average truck chassis is unsuitable for passenger transport because the weight is excessive, particularly the unsprung weight, the center of gravity is too high, the gear ratios are unsuitable, the springs are too rigid, the frames, spring and axle tracks too narrow, the turning radius too wide, the steering too stiff, etc. I believe that an efficient bus corresponds very closely to an enlarged touring car. Briefly, it would be just as unsatisfactory to attempt to use a high-class twelve-cylinder touring car for general trucking purposes as it is to expect the average truck to give efficient and economical service when used to haul human freight.



The development of a new type of vehicle is an exceedingly slow process. Apart from the matter of design, an immense amount of time is necessary to prove out the value of the product. Approximately 25,000 miles of operation is required to find out what is wrong after samples have been placed in operation. One hears

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of engineers who claim to have completed a design of chassis and put it into production straight from the paper. Our experience has not been so fortunate, although on our engineering staff we have some exceptionally high-grade men. We also avail ourselves of the opinions and advice of many of the best-known engineers holding prominent positions with the larger manufacturers. In spite of this, occasional mistakes do occur; for example, take the manufacturers of ball and roller bearings. They are always asked to approve our layouts but in some instances after approval failures are experienced. Naturally, this is a very serious matter for us since the major part of the losses, such as cost of dismantling assembly, loss of vehicle time, etc., must be borne by us while the bearing manufacturer has only to supply new bearings.

We have since 1907 operated nineteen different types of chassis produced by domestic and foreign manufacturers, also twelve different types of bodies, and we have tested nearly all suitable standard engines from four to eight cylinders, also many different types of radiators, clutches, transmissions, axles and chassis frames. In none of these instances did we meet with entire success. No doubt those who have control of the operation of heavy vehicle equipment will appreciate the many difficulties with which we were constantly confronted. Of course, our lack of standardization proved a severe handicap.

On looking back one cannot escape the conclusion that the design and production of our own equipment was the logical procedure to follow, particularly when one considers the extremely valuable data at our command as a result of experimental and development work plus the known results obtained from the operation of many different types. We certainly were in a unique position because we were able to select the best points from the numerous different types of vehicles operated by ourselves. Furthermore, it was not necessary to take precedent into account, nor to cater to other people's views. Then, again, we had no selling problems. The net result of our effort was the production of complete busses that have to date covered more than 20,000,000 miles. The performance of these vehicles has more than justified our fondest hopes and their operation is so markedly superior to our previous models that no comparison is possible. The enormous saving in gasoline and mechanical maintenance has been sufficient to meet the ever-rising costs of labor and material. It is reasonably safe to assume that had we not taken this step the company could never have reached its present position.

It is difficult to say what the future type of bus will be. Clearly, different cities have different requirements. In all probability, any large operating company will require at least two distinct types, the double-deck for large loads and the single-deck for smaller loads, faster operation, express service, etc.

Assuming good roads, wide thoroughfares, and reasonable freedom from overhead structures, the fifty to sixty-passenger, very low hung, double-deck vehicle capable of handling a trailer seems to have great possibilities. This class of vehicle jointly operated with the single-deck, one-man controlled, pneumatic-tired bus appears to me as being a logical scheme, especially where peak loads must be handled largely without surface car or subway aid. The development of either type presents immense, but not insurmountable, difficulties. We have been working to this end for several years and our sympathies are with those who may be undertaking a similar service.

There is just one other point. There are those who believe that the trolley car propelled by a gasoline power unit may supersede the present arrangement. In my judgment this theory will not bear close analysis, for the greatest asset the trolley car has is cheap power. Take this away and the structure falls to pieces. A gasoline-propelled trolley car is a bus, less nearly all the advantages of the latter. It is, of course, true that a much lighter and better design of trolley car could be produced and a gasoline power unit embodied in it. It is equally true that the cost of operation of such a vehicle might be less than that of existing types of trolley cars, but my contention is that if the same care and attention to design were applied to the conventional article, still better results would be achieved. The fact is the present trolley car design is more or less crude and out-of-date. They are as a whole built as strong as possible, not as weak as possible, which is a much more logical and economical procedure. To sum up, trolley car design has not marched with the times.

Research Department

This department coordinates the work of the design, repair and operating departments. Briefly, the duties and responsibilities of the research department are as follows:

(1) Analysis and recording of all breakages, failures, etc.
(2) Operation of the dynamometer
(3) Continual study of the fuel situation
(4) Testing of materials such as fuels, oils, etc.
(5) Perusal of all trade journals
(6) Standardization program

As regards the analysis and recording of all breakages, failures, etc., we attach great importance to this matter. The data are tabulated in such a manner that accurate comparisons can be made. Standardized classification sheets are furnished departmental heads weekly. Operating and repair departments are required to forward all broken parts to the research department, where full and complete records are maintained.

Among other apparatus the research department has a 150-hp. Sprague dynamometer. This is employed for the testing out of all engines, either new or repaired. Of course, it is also employed on work of other kinds.

A large amount of research work is done in connection with the continual study of the fuel situation. Various kinds of mechanical and chemical gas-saving devices and compounds are constantly under test, as well as thermostatic controls for air and water, carbureter improvements, etc. Our dynamometer equipment permits us to determine the value of these devices speedily. Where merit is shown, further tests are continued on the road under actual service conditions.

The testing of materials such as fuels, oils, etc., requires scarcely any comment. Obviously, it is necessary to assure ourselves from time to time that the materials delivered are in accordance with the specifications; for example, that the oils possess the required physical properties, that the gasoline is free from impurities, acidity, etc., that the range of boiling points is reasonably satisfactory, that our rubber tires possess the required resiliency, etc.

The research department is the medium through which we keep posted in regard to all developments in the industry. All trade journals are carefully scanned with this in view. Frequently small tools, methods of doing work and improvements of one kind or another are found in this manner that might otherwise be missed.

Where improvements are tested and show definite merit, it is the duty of the research department to make recommendations in regard to the embodying of these improvements in our equipment. This is done during the annual overhaul process. This department is also required to find remedies for defects which prevent our vehicles from operating their allotted mileage between general overhauls. Such improvements are also usually embodied during the annual overhaul process, although occasionally we standardize and apply certain minor features at other times.

Our system of records is very complete. Comprehensive data are kept showing the results obtained from the use of practically every device of any consequence that we have ever built or tested. We make use of photographs wherever it is possible to do so; for example, we photograph our jigs, tools, patterns and our parts grouped under the various sections for use of both stores and mechanics. We obtain invaluable information from the data gathered in connection with service failures.

Mechanical Department

The superintendent of equipment has charge of all constructional work including repairs and renewals. He is responsible for the selection, training and discipline of all personnel concerned therewith. His duties and responsibilities are broadly outlined under the chart heading "Mechanical Department." In dealing with this department, I propose to describe in detail only the functions that are peculiar to the bus business.

In general, the engineering and production problems in connection with the manufacture, maintenance and repair of bodies, chassis and spare parts are thoroughly understood by automotive engineers.

In describing the transportation department, reference is made to the manner in which we deal with the human side of our business. Much stress is laid on the methods used in connection with the selection and training of our employes. The appointment bureau, association, sunshine work, restaurants, recreation rooms, etc., are also briefly described. Of course, all departments share these privileges and the same general principles obtain in connection with the handling of personnel throughout every department. We are convinced that our success is in no small measure due to the adoption of these principles.

Practically all departments are dealt with under what we term "Personnel Establishments." These provide a definite number of men and hours for each class of work. Each week a detailed comparison is made up from the actual payrolls and copies are furnished departmental heads concerned. The establishments are very carefully prepared in the first place and from time to time they are revised. The point is that after having allotted a certain number of men and hours for each of the various sections we do not permit of variations either way, since additional hours must denote wasted effort; on the other hand, a decrease might be equally costly in the long run, for assuming our estimates are correct, any decreases must mean the omission of work which ought to be done and which being left undone must eventually result in deferred maintenance, which we know from experience is a very expensive matter. After establishments are approved, any shortages in personnel may be made up without special authority. We find this is particularly helpful, since under these circumstances there is at no time any question as to whether a man who has just been taken on is really wanted.

Repair Department

Briefly, the repair department is responsible for the carrying out of our annual overhaul program, the supply of properly repaired units to the operating departments, and in addition it undertakes major repairs to bodies and chassis due to accidents, etc. Fortunately, however, these are infrequent.

We believe in centralized unit repairs. This work is carried out in a department entirely separated from the operation end. To permit this, each operating department is allotted a definite percentage of spare units which from time to time are exchanged. Insofar as possible, the exchange is made on a mileage basis and we insist that the units be delivered and returned complete in all respects. Operating departments are neither expected nor permitted to make major repairs to units. The centralization of our unit repairs permits of the use of unskilled labor, and to this end special tools and labor-saving devices have been developed to an unusual degree. Also men are concentrated on each of the various sections and each section has allotted to it complete tool equipment covering its requirements. Engines in particular receive careful attention. Bearings are reamed, not scraped. After overhaul the engines are run in by belt, then lightly under their own power. Finally, they are transferred to a dynamometer where they are adjusted to prearranged standards.

Every twelve months each vehicle is automatically withdrawn from service. It is then stripped down completely and rebuilt. At this time improvements suggested by the research department after having been approved are embodied. The complete bus is rebuilt and repainted, then returned to the respective operating department, to all intents and purposes a new machine and in many respects a better one than the original design. This procedure, of course, has no small bearing on the matter of depreciation, for under these conditions depreciation is really governed by obsolescence. Our idea is that equipment must always be kept up as near to 100 per cent efficiency as possible, and as a matter of fact a vehicle, although it may have seen several years' service, is actually, at the expiration of this time, in a better mechanical condition than when it was first built. However, owing to the newness of the industry, the obsolescence factor cannot by any means be lost sight of.

Annual overhauls are carried out on a definite schedule. Two per cent of our total equipment is allotted for this purpose, eight working days per vehicle. A small percentage of spare units, such as engines, transmissions, axles, bodies, etc., are employed. In the process of the annual overhaul, no special effort is made to replace the same units.

Operating Departments

The function of each operating department is to maintain between annual overhauls the equipment allotted to it. Each department is controlled by a foreman who reports direct to the superintendent of equipment. The foremen are responsible for the cleanliness and general efficiency of the equipment allocated to them. This equipment consists of sufficient busses to meet schedule requirements, plus a certain number of additional vehicles to cover general overhauls. No spares are provided. The operating department foremen are responsible for both day and night forces. They are assisted by sub-foremen and charge hands. The wages, hours of work and duties of all operating department employes are clearly shown under their personnel establishment. As previously

stated, operating departments are not required to carry out major repairs. This work is dealt with by the repair department, which also furnishes the operating departments with overhauled units. The organization of departments other than general overhauls and gasoline efficiency will not be referred to, since the duties of these departments are largely of a routine nature and follow conventional lines.

A general overhaul represents a thorough inspection of every part of the body and chassis of every vehicle after each 2000 miles of service. General overhauls, or as they might be termed "general inspections," are the most important function of operating departments. We attach great importance to our theory of general overhauls. We feel it is essential to have a vehicle that can be operated for a reasonably extended mileage with what practically amounts to no mechanical defects. We then take this vehicle out of service in accordance with a prearranged program and it is gone over in the most thorough manner imaginable. This system permits of concentrated and organized effort with the minimum lost motion.

Very little repair work is done at night. Our aim is to concentrate on general overhauls. Under these circumstances, inspections, repairs, adjustments, etc., are carried out under almost ideal conditions. It is essential that the space allotted to this class of work has abundant natural light and it must be dry. Furthermore, sufficient time must be given to enable the work to be done satisfactorily. The net result of this procedure permits of attracting and retaining the class of help required, which must be of the best.

Approximately 6 per cent of our equipment is required for general overhaul. General overhauls must be completed by 4:30 p. m. each day, at which time they are scheduled for service. This means that up to 4:30 p. m. on week days we operate 92 per cent of our equipment and after that time 98 per cent. Saturday afternoons and Sundays we aim to operate 98 per cent. There are very few cases where this is not done, assuming, of course, that the requirements call for this service.

We have adopted the following general procedure in connection with the carrying out of general overhauls:

(1) A sheet is posted in each garage showing cumulative daily mileage of each bus from the last overhaul; from this sheet it is possible to see at a glance which vehicles are due for general overhaul
(2) The day previous to general overhaul each vehicle receives a special examination on the road by a qualified inspector; reports of this inspector are attached to general overhaul sheets. A special form is provided for this and on it are printed the items inspectors are required to examine
(3) At night as the busses are turned in a specially trained mechanical inspector meets them at the garage entrance. The drivers hand their report cards to this inspector and at the time take up with him any matters that seem of more than ordinary importance
(4) The night previous to the general overhaul the mechanism is thoroughly cleaned. The bus is then placed over a pit ready for an organized attack on the following morning
(5) The general overhaul sheet, which represents the history of a bus since its preceding general overhaul, is withdrawn from its binder, totaled up and placed on a board hung at front end of the bus. This sheet shows the drivers' names, mileage, gas and oil consumption; also the defects reported each day since the last general overhaul. There is also entered on the sheet a statement of the gas and oil averages of the vehicle as compared with the other vehicles operating from that division. The general overhaul sheet for each bus is brought up to date daily. The necessary data are obtained from the conductor's day card, the driver's report card and the division gas chart. The last item is described below
(6) During the process of general overhaul, gangs of specially trained experts deal with the various units. There is printed on each general overhaul sheet a summary of the duties of each section, the parts to be inspected, etc. This process is followed rigidly without any regard for the apparent condition of the vehicle. Details of the defects, if any, are obtained from the daily report card, which is carried on each bus. The drivers are required to enter chassis defects and the conductors all matters pertaining to the body

Throughout the year we average about 6.5 miles per gal. of gasoline. This figure takes into account all shrinkages, leakages and losses of every kind and description. There are a very large number of high individual averages, some as high as 15 miles per gal. We have a number of men who can give us 10 miles per gal. for weeks at a time. Of course, there are other men who give us low averages, but this is to some extent controlled by the class of service; for example, busses doing short mileage during the congested period of the day only are seldom high on our lists.

There are many reasons why we believe it is essential that special care and attention be paid to the matter of fuel economy. High gasoline averages from our standpoint mean

(1) Economy
(2) Well-designed and maintained equipment
(3) Skilled and contented operatives

Gasoline is our second greatest item of expense. Our yearly bill is in round figures $500,000. Since 1 per cent of this amount represents $5,000 annually, it can readily be seen that losses of even 1 or 2 per cent must be remedied, regardless of whether these losses are due to mechanical or physical disabilities. Increased labor and material expenses, and gasoline falls under the latter heading, cause us much greater anxiety than if we were manufacturing in the ordinary sense of the word, for we are selling a commodity which has a fixed price regardless of production costs. This means that every addition to our labor and material bills must be paralleled with some form of economy. If this were not done, we would soon find our expenses in excess of our income. For example, in 1911 our gasoline consumption averaged 2.9 miles per gal. At that time gasoline cost much less than it does today, and if it had not been possible to increase our gasoline efficiency enormously it is quite possible that the Fifth Avenue Coach Co. would now be out of existence. Not only is our gasoline bill the second greatest item of expense, but it is capable of greater reduction with less effort than any other single item. Furthermore, in achieving high averages, we accomplish at the same time many other desirable things. Our rising and falling gasoline averages are in effect the barometer on which we base our predictions. The gas barometer tells us in the most unmistakable language what is in store for us. Bad gasoline consumption means big fuel and repair bills with the prospect of still bigger bills in future; possibly also labor unrest due to general dissatisfaction.

To attain high averages it necessarily follows that one must employ well-designed and maintained equipment. Our vehicles cover an average of more than 100 miles per

day. They are required to stop and start about 1000 times a day with several thousand gear changes, brake applications, etc. Furthermore, each vehicle is handled by several different drivers daily. None but the best materials will stand up under such conditions.

Where high averages are obtained there can be no question that both drivers and conductors are willing and anxious to serve the best interests of the business, and one knows that this cannot be the case unless they are interested in their work and are happy and contented.

The following ways and means have been adopted to secure and also to maintain high averages:

(1) All engines are put through a standard dynamometer test before being issued to the repair and manufacturing departments. After engines are installed few, if any, adjustments are found necessary other than the changing of jets

(2) There is posted in a prominent position in each garage a sheet which shows daily the number of miles per gallon of gasoline for each vehicle. This sheet is constantly referred to by members of both mechanical and transportation departments. This information gives us a definite basis on which to work and it also permits all concerned to be in a position to see the results of their efforts

(3) There is attached to each division one fuel expert and one driver who is not assigned to any definite run. The latter's work consists in taking out and operating in regular service busses showing low averages. His assignment is arranged between the fuel expert and the transportation foreman. We choose the most efficient of our drivers for this work. Obviously, the advice of such men is of the greatest possible value to the fuel expert

(4) The fuel expert is provided with a special kit of tools together with an assortment of various jets. No carbureter adjustments are made by men other than the fuel experts. All jets are numbered and carefully calibrated and a proper record is made of all jet changes. The carbureter itself is specially built to give high economy

(5) From time to time we organize various kinds of gasoline contests. In some instances, details of these contests have been published in the trade papers. These contests are useful not only because of the direct bearing they have on our gasoline and repair bills and mechanical efficiency generally, but also because they tend to create better fellowship, a friendly spirit of rivalry, a keener and deeper interest in our business and a closer understanding of our aims and aspirations, in short, our policy

(6) There is issued to the various departmental heads a weekly summary showing divisional gasoline averages. Comparisons are made with the previous week and also with the corresponding period of the previous year

Transportation Department

The superintendent of transportation has charge of selecting all men for the transportation department, supervision of their training, administration of discipline, elimination from service, promotion, general study of traffic conditions, collection of statistics upon which running time and schedules are prepared, supervision of inspectional forces, receivers, timekeeper's and mileage departments, division foremen, etc. In this work the superintendent has a supervising force of forty-five men comprising foremen, heads of various departments, inspectors and starters.

The chief of the appointment bureau is responsible for all men employed. Generally, employes recommend applicants. Qualifications are preferably married men, 25 years or over, and those with Army or Navy training. Applicants must be over a specified weight and height. All applicants are courteously received by an examiner who questions them as to their previous experience. Those who qualify are permitted to fill out applications. They are then passed on to the chief, who questions them further as to their general qualifications and knowledge of the city. If accepted, the applicants are sent to the company doctor for physical examination and eyesight test. The superintendent of transportation then gives each applicant a short lecture on the policies and aims of the company. His photograph is taken by the company photographer and he enters the conductors' instruction school. His references for five years are in the meantime investigated and those references within 25 miles of New York City are checked up by a personal investigation. Only 20 per cent of all applicants qualify for the position of conductor.

The chief conductor instructor points out to students the duties they are required to perform, emphasizing courtesy toward passengers and the prevention of accidents. Each student is then given various forms and descriptive matter and instruction in detail on these follows. Students are assigned to conductor instructors on the road to receive a practical working knowledge, and then return to the school for a final examination. Those passing the oral, blackboard and written examinations with a proficiency of 75 per cent are recommended for appointment. Others receive further instruction until 75 per cent proficient. On an average, the instructional period covers four days. On the completion of the instructional period, the student is given a certificate by the chief conductor instructor which he brings to the appointment bureau. Assuming satisfactory references, the student is then outfitted by the company tailor. Finally, he is assigned to a division where a "get together" talk is given by the foreman before starting work. All new men are on probation for ninety days, during which time the chief conductor instructor rides with them as often as practicable for follow-up instruction, because it is impossible to inculcate all details of a conductor's position while in the school.

The men who man our busses, including instructors, inspectors, starters, etc., must all graduate from positions as conductors. Where men prefer to remain as conductors, no objection is raised. Based on averages, each conductor has an opportunity to become a driver after eight months' service. We attach great importance to the educational value of this system. A conductor soon learns traffic regulations. He becomes familiar with the requirements of our patrons. He also has the best possible opportunity to see and feel the results of misoperation. A driver without a conductor's experience can scarcely realize what a conductor must contend with and he would be less likely to cooperate with the conductor. His experience as a conductor insures that he is aware at almost all times of exactly what is happening at the rear end.

Promotion to driver, which involves an increase in pay of 13 per cent, is determined by seniority. Promotion also depends upon the man's record while employed as a conductor. This prompts conductors to keep their records clear of violations. Conductors are recommended for promotion by their foremen and reexamined by the doctor. If passed, the records are examined by a board of review consisting of the superintendent of transportation, the chief driver instructor and the chief conductor instructor. If approved by the board, they are placed in the drivers' instruction school.

The chief driver instructor points out to the students the duties they are required to perform. They are then shown on a stripped chassis the various units and the relation these units bear to the operation of the bus. Then they are sent to a divisional instructor and receive practical experience in driving on the road without passengers. Every third day the students are sent back to the school to receive additional mechanical instruction.

Upon passing the State examination and a license being granted, the student is permitted to drive a bus carrying passengers, under guidance of the service instructor, until competent to become a driver. He is then given a test by the chief driver instructor and if found satisfactory is recommended for appointment and assigned to a position as a driver.

On an average the instructional period covers sixteen days of 10 hr., the 160 hr. being divided into 45 hr. of mechanical instruction, the same amount of driving instruction without passengers, and 70 hr. of driving instruction with passengers. As in the conductor's instruction, follow-up instruction is also given. From the time each man files his application for a position as a conductor to the time he is made a driver, the company expends practically $200 for his instruction.

Complete records are kept of each man. These are in folder form and consist of

(1) Application
(2) Reference blanks
(3) Photographs
(4) Doctor's examination certificate
(5) Complaints and commendations
(6) Violations
(7) Accident settlements

The first part of the record consists of sheets arranged in chronological order showing entries of all violations, complaints, commendations, accidents, etc. When a conductor becomes a driver, the same record is continued and there is attached thereto his record of instruction as a driver, the doctor's reexamination certificate and the employe's contract; also a sheet showing entries of all delays together with reports covering their investigation.

In the instructional period students are paid. This is in reality a loan and a contract is made in which it is stipulated that if the student remains as driver six months or longer, the loan is discounted. If he leaves the service prior to expiration of the six-months' period, the loan must be paid out of any wages due him.

Busses are run in accordance with time-tables very similar to those of any steam railroad. The construction of our time-tables is a most difficult and expensive matter, much more so than with steam railroads and electric surface or subway systems. Because of the varying traffic conditions along our routes, we are obliged to have no less than six different running times. Of course, these are based on average conditions, since it would be impracticable to meet every variation. Any simplification of our time table arrangements must immediately result in a decreased speed. This would be unsatisfactory to the public and immensely costly to us. Our annual payroll for drivers and conductors is in round figures $1,000,000; therefore a 1 per cent decrease in speed represents $10,000 added to our wage expense. There are also changes in the different periods of the year and it is necessary to build new schedules when these become effective. Schedules must also be changed to take care of the varying conditions of riding. This change in riding must be closely watched and passenger counts are constantly taken at various points to determine just what service is necessary. Altogether there are ten time table changes throughout the year and modifications almost weekly.

There are nine separate lines, all of which converge on Fifth Avenue below Fifty-seventh Street. For the different periods of the day we at present operate the following number of busses per hour:

Period	Busses per hr.	Headway, sec.
Morning rush	193	18
Midday	107	33
Evening rush	184	20
Sunday	144	25

Foremen, chief instructors, inspectors and starters patrol the routes for the purpose of regulating the operation of the busses and to give follow-up instruction to new conductors and drivers. We also employ an average of twenty operatives, in civilian clothes, in our inspectional bureau to check general operations on the road. Inspectors also make hourly checks of schedules, report bad pavement conditions and defective equipment; check conductors' register readings and talk to the men on minor violations. Serious infractions of rules are reported to the respective foremen of transportation. They in turn give a man four chances before sending him to the superintendent of transportation. We have instituted the "right of appeal" so that a man who feels an injustice has been done can take his case to the general manager and, if necessary, to the president.

Crews are allowed 10 min. each morning and night for an inspection of their busses. The depot dispatcher is responsible for seeing that the busses leave the garage on schedule time. As soon as a bus reaches the terminal, it is then under the direction of the starters and the inspectors who direct the busses in accordance with schedules, copies of which they are provided with in small book form.

Arrangements must always be made ahead of time for the numerous parades traversing our routes. New routes must be selected and looked over for overhead structures, pavement conditions, etc., and men have to be stationed at the points where we turn off our regular routes and also those unprotected by traffic policemen, as well as at points where there are overhead obstructions. While parades do cause us considerable losses they do not prevent our operation, since it is simply a question of selecting other routes. Our organization provides for a number of alternative routes which have been previously surveyed and the points established where men are required for directional purposes, etc. This is a very convenient arrangement and permits of changes being made on very short notice.

We maintain a fleet of thirty-eight snow-plows and five sand-cars, with which we keep our routes open through the winter. The snow-fighting force is patterned after the fire department. Each section of our routes has its allotted plows in charge of a captain. Our organization is arranged so that regardless of the time of day or night a snowstorm starts, the required men automatically report for duty. When such conditions obtain, a complete system of centralized control automatically becomes effective.

We have an association for all employes which insures them for a nominal fee with death and sick benefits; also the free use of the company's doctor. We have a sunshine nurse and sunshine committee who take care of those who are ill or in trouble. In addition, we maintain a pension fund. We often give free legal advice through our attorneys to employes. Restaurants, recreation

rooms, barber and tailor shops are maintained for our employes at each of our garages. We even provide sleeping accommodation in the winter for men who cannot get home because of unfavorable weather conditions so that a man can practically live at the plant with all the various accommodations provided. In our restaurants food can be obtained at practically cost price. The same applies to our barber shop. The service of the tailors is gratis. We have a house organ, *Bus Lines*, to which employes contribute items of interest, and generally the business is run on the basis of one great, big, happy family.

Future Possibilities of the Motor Bus

It has already been pointed out that motor-bus operation is a comparatively new art. The possibilities of improvements, more especially from the standpoint of design, are practically unlimited. This applies with respect to greater comfort and convenience as well as economy of operation. These remarks do not apply in the same degree to any other form of surface transportation. In most cases, other systems are providing all the comfort and convenience that can reasonably be expected. Furthermore, it is scarcely to be hoped that further operating economies can be effected. As a matter of fact, insofar as one can judge, costs will rise rather than fall, for with the present high rate of personal and real estate taxes, high rate of wages, high cost of materials, etc., the greater the investment in property in relation to the gross income the less will be the possibility of profit. The bus requires the minimum investment in garage and repair facilities. The lower unit cost is a powerful argument in favor of its adoption.

Unquestionably if a motor-bus service is to realize its possibilities of financial success, it must be backed up not only by ample resources, but it must also develop a highly specialized organization. Experienced management and direction is imperative. The engineering force requires a special experience, for the demands upon the motor bus are quite distinct from the demands made upon any other type of motor vehicle. The needed traffic studies and schedule making are unique. The employes must be trained in a branch of motor-vehicle operation with many distinct and unique peculiarities for which the operation of neither the automobile nor any form of surface transportation affords suitable training. One of the chief differences between the bus and other forms of surface transportation is the matter of flexibility. As a matter of fact, we prefer to train men for drivers who have never had automobile driving experience. Furthermore, we find that railroad operatives, while they do possess useful knowledge, require to unlearn so much that on the whole it is more satisfactory to employ men without this experience.

Unquestionably the wisest policy both from a financial standpoint and the service results to the city is to entrust a single well-organized and equipped company, possessing ample resources, with the development of a unified motor-bus service. Parcelling out streets to two, three or more companies will never provide the Pullman car service which the true motor bus can give. If the parcelling out process is adopted and the several companies are of a nondescript character with the usual type of jitney equipment, the outcome can only be chaos. The actual result of any form of competition must be multiplied fares and no transfers. With a unified system there can be no harmful monopoly, for the fare should be determined by the authorities and the company should be under public regulation, but so-called competition from a public utilities standpoint means bad service and financial failure. Cities cannot be prosperous without efficient utilities and utilities cannot be efficient without prosperity. To cite an example of the evil effects of bus competition, one need only point out London's early bus experience. This soon convinced both the stockholders and the general public as to the unwisdom of this policy.

No satisfactory motor-bus service can be given with seats for all on the basis of a 5-cent fare. It costs the Fifth Avenue Coach Co. about 8½ cents for each passenger carried. A large proportion of our daily mileage is operated at a loss. Checks show us exactly where these losses occur, but we do not try to avoid them. We are satisfied that by careful management on the whole a profit can be made and that in the long run we should surely lose if we merely cut our service to suit local conditions. We know that our success must depend on the good-will of the public and it has always been our aim to give in exchange for our earnings an equivalent measure of helpful service.

Unquestionably in the larger centers it is desirable that the workers should be able to get away from the busy centers of industry and congestion to more wholesome home surroundings in the outlying districts and everything should be done by city authorities to encourage this. Nothing is of more importance in this respect than providing expeditious, healthy, comfortable and easy means of public conveyance to and from these points. Of course, the development of the outlying districts raises values so that the city will in this manner obtain increased income from taxation. This is quite an important consideration.

Clearly, where car tracks do not already exist, the most careful thought should be given before they are installed. Quite apart from this, from a public service as well as an operating point of view, there can be no question as to the possibility of using busses for

(1) Extending the service of existing car lines by a bus system into the outlying districts through the introduction of transfer privileges between the two

(2) Extending service, the conditions of the streets permitting, into outlying districts without a transfer between busses and the cars and without disturbing the present local business or business logical to the existing car lines by permitting the busses to operate beyond the present outlying terminus of street cars and diverting the busses to other parallel routes after reaching such outlying terminus

There is one point I should like to make particularly clear. In my judgment, no type of bus designed up to the present is capable of properly handling peak loads. Of course, there are possibilities in regard to a suitable development along these lines, but as yet these have not been achieved. In my opinion, the theory that the car systems in any of the larger cities can be supplanted by any standard type of bus now obtainable is absurd and not worth any serious discussion. No man with any elementary transportation knowledge would think of backing such a statement. The bus is not more economical than the trolley car on the basis of cost per passenger carried, which is the only real basis. Obviously, it is useless to compare the cost per mile of two vehicles of such vastly different seating capacity.

It should be borne in mind that the financial success of the Fifth Avenue Coach Co. is largely due to the 10-cent fare. On a 5-cent basis its development would have been absolutely out of the question. In saying that the bus cost per passenger carried is not less, and is perhaps

greater, than that of the trolley car, I should also add that I am sure the public will gladly meet the difference since the comfort and convenience of a bus have much greater possibilities than is the case with the trolley car.

Conclusion

Few, if any, of those who ride in the Fifth Avenue Coach Co. busses realize what kind of an organization is necessary to give the public the class of service provided. This is particularly true of those interested in promotional schemes. If the average promoter did realize the relatively small margin of profit and the countless pitfalls, he would most certainly steer clear of the bus question. To attain success in the operation of motor busses is not a simple undertaking. The truth of this is evidenced by the number of companies that have failed as compared with those which have been successful. Railroads and street cars have years of precedent to guide them, but this newer form of transportation is as yet in its infancy.

The policy of the Fifth Avenue Coach Co. from an outside viewpoint may be summed up into two words, "service" and "courtesy." From an inside viewpoint we aim to give every member of our organization a square deal in all that the word implies. With us the word "justice" is not merely an empty phrase. The "right of appeal" guarantees this. The doors of the executives' offices are always open and heads of the departments as well as the rank and file have free access at all times. We believe in cultivating constructive criticism, and with this in view frequent staff meetings are held when all members have an opportunity to express their opinions. These meetings also enable the staff to maintain that close personal touch with the management without which real cooperation is scarcely possible. Our staff officers are carefully trained. They are taken into our confidence where matters of policy are involved and their views are eagerly sought. They are most courteously treated and they in turn so treat their subordinates, for we all know that in any industry the men in the ranks take their example from those at the top.

We also aim to pay at least as good, preferably better, wages than can be obtained in businesses of a similar class. Our working conditions are just as good as we know how to make them. The net result is that labor troubles are conspicuous by their absence. Lastly, our labor turnover is small and we always have more applications for positions than we have positions to offer.

Perhaps it is not out of place to say that we are extremely proud of our organization. We possess unequaled garage facilities, splendidly laid out and well-lighted shops, modern machine-tool equipment and a personnel that knows not the word "failure." Practically every member of our staff has worked his way up from the ranks. Our organization is not a one-man proposition in any sense of the word. Each man is willing and anxious to do more than is expected of him and to subordinate his personal interest. We all believe in the theory and practice of teamwork and so it naturally follows that the operation of our business is extraordinarily free from petty jealousies and from other forms of industrial unrest. At least, that is our position today and there is nothing on the horizon to cause us to fear that there will be any change in the future.

HIGHWAY TRANSPORT SURVEYS

IN making surveys relative to the establishment of highway freight transport lines, the following items should be carefully considered:

All year around road conditions, including bridges
Rail freight and express rates
Frequency of existing service
Time of delivery of existing service
Amount and kind of freight moving in both directions between the points in question
Running time possible
Sentiment of the district under consideration toward existing and proposed service
Sufficient financial support
Traffic laws, ordinances and regulations

Road conditions will determine the kind of equipment that can be operated. The amount and kind of freight will determine the size of the unit, and number necessary, from which can be determined the expense, to which should be added, this is most often omitted, overhead charges, the cost of soliciting business, storing and handling, superintendence, etc., which run very high. The cost of operation will determine the rate. This compared with existing rates and services will indicate whether business can be secured under such costs.

In a survey recently made of the possibility of establishing inter-city motor-truck routes it was concluded that the lowest capacity truck that could be operated, considering the rate that could be obtained, was a 3-ton. The operators disregarded this and started in with 2-ton trucks. Although they were loaded to 80 per cent of their capacity on every trip, in both directions, they could not pay, the result being, as might have been expected, failure.

Reliability is absolutely necessary. In the case of highway passenger transport, the number of passengers will determine the seating capacity desired and the frequency of operation, which together with the length of haul will show the operating expenses and, therefore, the fare that must be charged.—F. Van Z. Lane.

TANK ATTACK EXPERIMENTS

INTERESTING as well as instructive tests have been conducted at McCook Field to determine the relative value of bombs and the new 37-mm. cannon when used to attack tanks at low altitudes. A Martin bomber on the nose of which a 37-mm. cannon was mounted flew over the target a number of times at an altitude of 100 ft., traveling at the rate of 120 m.p.h. The first three shots fell a foot short. The remaining five were direct hits. A De Haviland 4 loaded with eight fragmentation bombs was flown over the target. The bombs were dropped singly to obtain the range and fell about 30 ft. wide of the target. On the next circle of the field the remaining six bombs were dropped in salvo. Two bombs made direct hits, the remaining four passing over the target at a height of 3 or 5 ft., striking less than 30 ft. beyond the target. If the target had been an actual tank all six bombs would have registered direct hits. The results are considered remarkable as the entire test was carried out below 100-ft. altitude.—Air Service News Letter.

Discussion of Papers at the Truck and Tractor Meeting

THE discussion of the papers presented at the 1920 Chicago Truck and Tractor Meeting of the Society included written contributions submitted by members who were unable to be present as well as the remarks made at the meeting. In every case an effort has been made to have the authors of the several papers reply to the discussion, both oral and written, and these comments, where received, follow the discussions. For the convenience of the members, a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, in case it is desired to refer to the complete text.

DECREASING UNSPRUNG WEIGHT BY THE USE OF ALUMINUM

BY A. H. EDGERTON

STATING the desirability of reducing unsprung weight in motor vehicles as a recognized fact and that 75 of 100 engineers interviewed favor such reduction, the particular advantages resulting are given as improved riding qualities, economy in tire wear and better acceleration. Mathematical deductions to establish the most desirable ratio of sprung to unsprung weight are not attempted, the intention being rather to state the reasons favoring lighter wheels and axles.

Unsprung weight effects depend primarily upon the ratio of sprung to unsprung weight. No data determining the most desirable ratio are available, but an investigation of the proportional weight of the unsprung and sprung parts of good-riding-quality automobiles showed it to be about 1 to 3. By constructing the wheels and the axles of light metal it is possible to maintain such a ratio, assure good riding qualities and reduce the total weight.

Laboratory and road tests prove that more mileage can be obtained from a light than from a heavy wheel. A comparative test was made between an aluminum and a steel wheel mounted at opposite ends of the same rear axle of a truck, each equipped with a 36 x 6-in. tire. Running on the surface of a drum having cleats to cause shock, the tires and wheels were subjected to a total of 6,009,300 impacts. The steel-wheel tire showed deep cracks, but that on the aluminum wheel only small fractures; there was no trace of any metal fatigue.

By decreasing the wheel and axle weight, the inertia that must be overcome in accelerating is reduced proportionately. In the test described, the moment of inertia of the aluminum wheel was 53 and that of the steel wheel 123. The force needed to produce a given angular velocity of the wheels in a given time is directly proportional to the moments of inertia of the wheels. It follows that an aluminum wheel consumes less power in attaining its angular velocity than a wheel of the same mass distribution but of greater weight. [Printed in the January issue of THE JOURNAL]

THE DISCUSSION

A. Y. DODGE:—It was mentioned that 500 lb. of wheel weight was saved. On what size of truck can this saving in weight be made? What is the size of the truck upon which the dynamometer tests were made?

A. H. EDGERTON:—The truck on the dynamometer stand was a 2-ton truck loaded to capacity. The aluminum wheel weighed 82 lb. and the steel wheel 248 lb. The comparison was consistent, as there was no tire on either wheel.

F. D. HOWE:—Is there a definite figure for the ton-mileage obtainable from a set of tires on the lighter aluminum wheels, as compared with that obtainable with the heavier steel, or wood, wheels? The wheels will cost more. Will this additional cost be compensated for by greater tire mileage?

MR. EDGERTON:—I have not investigated that phase as yet. The wheel has been in an experimental stage; we have had many problems and have never made any comparisons. The information is I think easily obtainable by calculation or by comparison.

A. E. WINKLER:—How does the advantage gained by the application of aluminum wheels to trucks compare with that gained by their application to passenger cars?

MR. EDGERTON:—We have built a passenger-car wheel that differs greatly from the orthodox wheel, the difference being in the construction of both the rim and the face of the wheel. It has the tire seated directly on the aluminum and the face is entirely unmarked by bolts or rivets. There is an advantage in weight of 7 lb. over the wire wheel and as much as 40 lb. over the steel wheel.

MR. WINKLER:—How were those wheels attached?

MR. EDGERTON:—They were detachable wheels.

A. B. BROWNE:—Have any actual tests been made of the aluminum wheels both before and after they have been in service?

MR. EDGERTON:—Our first action was to test the wheels before they went into service. We have a set of wheels which have been run several years; we expect to test them but have not as yet done so. It appears to me a waste of time. The wheels are apparently in as good a condition as they ever were. We have inspected them and hammer-tested them for cracks. I cannot believe that there would be any advantage in making a test after the wheel was run; however, we expect to make it.

JOHN MCGEORGE:—Has any test been made to determine whether the elastic limit has been exceeded, due to so-called crystallization?

MR. EDGERTON:—We have run the wheel under the vibratory action already described. We did not run it to destruction or to obtain a crystallization. A test of that sort would require much time, because this alloy has sufficient elongation to cause it to bend considerably before it breaks and I believe the wheel would not crystallize.

W. S. NATHAN:—Are these wheels die-cast or sand-cast? What parts are finished.

MR. EDGERTON:—All wheels have so far been sand-cast.

They are machined only on the parts subject to mounting, such as the tire seat, bearings and hubs, and such drilling as is required. The outside face of disk wheels for passenger cars is machined; otherwise, disk wheels are not faced.

B. M. IKERT:—What are the relative advantages of the spoke type of wheel and the disk type?

PRESIDENT J. G. VINCENT:—If one or the other has an advantage, has any difficulty in casting been found? Are there the same shrinkage strains that occur in steel or malleable wheels?

MR. EDGERTON:—We have made both spoke and disk wheels. There is very little difference as far as the foundry work is concerned. The hollow spoke on the spoke-type wheel requires slightly more core work, but the wheel has been equally successful in both types, finally. All tests indicate no advantages favoring one type over the other. The weight saving and the strength appear about equal in either case.

F. J. BEDFORD:—What is the effect on the traction balance due to lightening the unsprung weight? The point was made whether the traction would be as good with the lighter unsprung weight as with the truck as originally balanced, particularly with varying loads.

MR. EDGERTON:—We have made it a point to watch for any effect that might occur from that, but there has never been any noticeable result. With the truck loaded the wheels maintain the proper traction and do not slip; the light wheels do not spin more than heavy ones, nor are the tractive efforts unbalanced.

TRACTOR TESTING FROM THE USER'S STANDPOINT

BY LEON W. CHASE

TO test tractors for results valuable to the user, the reliability, durability, power, economy and utility should be determined. Standard tests measuring tractor utility and reliability are impossible practically and durability tests would be an extensive project, but tractor and engine-power tests and tests of the amount of fuel required for doing a unit of work can easily be made.

The University of Nebraska tests described were for belt and drawbar horsepower and miscellaneous testing for special cases. The four brake-horsepower tests adopted are stated. Tractor operating conditions are then reviewed. The drawbar horsepower tests include a 10-hr. test at the rated load of the tractor, with the governor set as in the first brake-horsepower test, and a series of short runs with the load increased for each until the engine is overloaded or the drive wheel slips excessively, to determine the maximum engine horsepower.

The special testing course devised and constructed is described and the plans for absorbing the power of the tractor stated. In this connection the Nebraska dynamometer car which was developed for work at the University is described and its operation explained. [Printed in the January issue of THE JOURNAL]

THE DISCUSSION

E. A. JOHNSTON:—I am familiar with Professor Chase's operations and believe that his plan of testing tractors will prove very satisfactory and be adopted generally. Several States are considering laws to protect the farmers and others have enacted such legislation. I believe in this and that if the prominent tractor manufacturers would cooperate by testing their tractors practically and adopt a standard method of rating, similar to the one adopted by Professor Chase, this would forestall much of the undesirable proposed legislation. I hope that all who are interested in the future of the tractor business will cooperate to secure a standard method of rating tractors.

D. BAKER, JR.:—Recently, a manufacturer gave no tractor rating and said he was awaiting a test by the State of Nebraska. Can a manufacturer advertise his tractor ratings, after testing, as certified by this State?

PROF. L. W. CHASE:—The Nebraska Legislature appropriated no funds for this tractor testing. The regents of the University of Nebraska supplied the money for the first year's work. As a result, we can test any tractor independently of the Nebraska tractor law. If any manufacturer should desire such a test, or, if we should desire to make any test for the manufacturer with his approval, such tests can be made on this apparatus independently of this law and the results may or may not be published, depending upon the arrangements made with the University of Nebraska. Relative to the official tests we are required to make and with which the tractor manufacturers are required to comply before they can sell tractors in Nebraska, the law says:

> The report of the official tests shall be posted in the agricultural engineering department of the University and in such other places as may be designated by it. The same shall be incorporated in the annual report of the State Railway Commission, provided that no tractor company shall use the results of said tests in such manner as would cause it to appear that the State university recommended the use of any particular model of tractor, in preference to any other type or model. It will be unlawful for anyone to publish such extracts without publishing the entire report.

A. B. BROWNE:—I have done much drawbar testing on drums but I believe that method would scarcely be applicable to tractor testing.

PROF. CHASE:—Professor Chatburn, of the University of Nebraska, has done considerable work along this line as it applies to highways.

ARTILLERY MOTORIZATION AS RELATED TO CATERPILLAR TRACTION

BY GEORGE W. DUNHAM

MOTORIZATION, as developed during the war, is stated as the greatest single advance in military engineering since the fourteenth century. Excepting about 66 per cent of the 77-mm. guns in the combat division, all mobile weapons of the United States artillery are motorized and complete motorization has been approved. The history of artillery motorization is sketched and a tabulation given of the general mechanical development in artillery motor equipment to May, 1919. Caterpillar vehicle characteristics are next con-

sidered in detail, followed by ten specifically stated problems of design which are then discussed. Five primary factors affecting quantity production, successful construction and effective design, in applying the caterpillar tractor to military purposes, are then stated and commented upon. A table shows specifications of engines used by the Ordnance Department and three general specifications for replacing present engine equipment are made. Ways and means of modifying present equipment are presented and the findings of the Westervelt Board that studied armament, calibers and types of material, kinds and proportion of ammunition and artillery transport methods are given in an appendix. [Printed in the March issue of THE JOURNAL]

THE DISCUSSION

COL. C. L'H. RUGGLES:—The Ordnance Department is much indebted to Mr. Dunham for the presentation of this paper. It is continuously in debt to many prominent members of the Society, not only for the efficient assistance they gave in the motorization program throughout the war, but for the interest they have taken in the development of artillery motor traction now that the war is over. We must not lapse into a false feeling of security. Conditions in the world are far from settled. Many bitternesses must remain, particularly in the defeated nations. Russia is an unsolved problem. It is by no means impossible that new combinations of nations may arise to threaten the peace of the world again. Therefore, it is incumbent upon this Nation to keep itself prepared.

The problem can be resolved into two principal factors, the training of the man power of the Nation and industrial preparedness. It is the duty of every good citizen not only to do his share to improve the conditions under which we live but to see to it that proper laws are passed by our representatives in Congress to insure the continuance of real freedom and to deal adequately with new conditions as they arise. Each one of us must be prepared to defend our country, its institutions and its laws, by force of arms against foreign enemies or enemies within its own borders. How can we do this unless each of us has at least an elementary training in the scientific use of military arms under trained direction? Universal training will improve our young men physically; it will give many of them ideas of citizenship and discipline they would not otherwise have; and, with adequate industrial preparedness, it will provide a strong arm for our people which will insure them from aggression from any source whatever.

Of the two factors of preparedness, the one which furnishes the greater problem and of which unfortunately we hear the least, is the factor of industrial preparedness, the munitions problem. In a war between powers of the first magnitude, all the industrial resources of the nations concerned will be strained to the limit and, should the United States be involved, we cannot hope again to have allies that will hold the enemy while we get our production of war material started. Therefore, we must be prepared with a reasonable amount of munitions on hand, with designs of new material embodying all the latest improvements in the military art perfected and ready for issue to our private industrial plants at a moment's notice; and these designs should admit of quantity production in the shortest possible time after their issue. The Ordnance Department should be familiar with the capabilities and capacities for munitions production of the various plants throughout the country, have plans made showing the kinds and amounts of munitions to be produced at the various plants, and endeavor to keep the management of the plants and the engineers of the country interested in and informed as to the latest war material designed or being designed.

At present we are fortunately situated. We have a large amount of munitions on hand which are as modern as any used during the war. Our manufacturers are now familiar with the production of such munitions, and thousands of engineers throughout the country have served in the Ordnance Department, while thousands of others have aided in the production of munitions in the various plants throughout the country. But these conditions will change. Certain kinds of munitions, such as powders, explosives, fuses and grenades, will deteriorate, and must be replaced. Guns, gun carriages, tractors, tanks and ammunition will become obsolete through the development of new and improved types, and younger men will take the place of the engineers and manufacturers who have served the country in and out of the Ordnance Department during the war.

The technical staff of the Ordnance Department is charged with the duty of establishing and maintaining a liaison with the engineering societies of the country, to keep alive the knowledge of and the interest in industrial preparedness that now exists. It has made a most satisfactory beginning in this work with the Society of Automotive Engineers which, at the request of the Ordnance Department, has appointed a committee to consult with the Department and advise as to the suitability of its designs, not only with respect to military requirements but also with regard to the production features, as it would be folly to produce designs on paper that cannot be manufactured rapidly by commercial plants when emergencies arise. The appointment of this committee is an assurance to the Department that it will not unknowingly deviate widely in its designs from good commercial practice, and that through the members of the committee the Department will be kept advised constantly as to the improvements in the automotive art applicable to military types. This committee has already had two meetings with officers of the Ordnance Department; one at Washington, and the other at the Rock Island Arsenal and Peoria. Both meetings have been of great assistance to the Department and increasing benefit from meetings is expected as the Department progresses with the development of its new designs and the tests of experimental material. It is expected to hold joint sessions of the committee and officers of the Ordnance Department every two or three months.

J. L. BREESE:—Referring to Table I and the values given for the pressure per square inch on hard and in soft ground, are the surfaces dependent upon the amount of penetration?

COL. L. B. MOODY:—Yes. In Figs. 12 to 15 details are given. The shorter the contact with the ground, the easier the steering becomes. Generally speaking, while the pressure on some of these machines may run high on macadam roads, that is not an objection. Our general specification is to the effect that the vehicle shall not sink into the ground to an extent that will interfere with steering and that the ground pressure shall not exceed 5 lb. per sq. in. Some of the war vehicles reached 7 lb. per sq. in. This is not excessive; 5 lb. per sq. in. is about a fair compromise.

MR. BREESE:—Four speeds and maximum torque at zero speed are desirable. This suggests the steam engine. Has anything been done along this line?

COLONEL MOODY:—The steam engine was tried in one of the tanks with the idea of obtaining maximum torque

with minimum horsepower. We continued the use of the mechanical transmission according to the consensus of the manufacturers' opinions.

JOHN YOUNGER:—The keynote of this paper is a plea that the lessons of the war should not be forgotten in times of peace, and that we should be preparing constantly for the next war. There will be a next war. During the last war a sword was hanging over us; as soon as this was taken away, the dollar took its place and all of us seem to be reaching out for that dollar, unmindful that the sword may return. We have a tendency now to forget Washington. We must overcome that. We must realize that the lessons learned during our connection in Washington must be remembered in times of peace, when we have time to think them out. They should be taken to ourselves and studied; we should keep not a fixed but a flexible policy, looking ahead and educating ourselves. The last war was a war of engineers; the next war will be a war of engineers. It will be a greater war, and it is only by the aid of engineers that the Army can meet the expansion necessary for war.

L. W. CHASE:—I believe that much greater sympathy should be shown toward the War Department. I was sufficiently close to the tractor section while in Washington to absorb many ideas on this subject. There should be some means whereby the farmer and the manufacturer can attain closer contact with the Ordnance Department, especially regarding the tractor situation. The tractor is an agricultural machine. The agricultural public absorbs this machine. I have hoped that some line of tractor manufacturing due to our war experience would be developed that would aid the agricultural public. I believe data are filed in Washington whereby the Ordnance Department could publish the results of many tests that it has made, through organizations similar to our Society. Even if the results of those tests caused the abandonment of the tractors under test, the results would aid the manufacturers who are now making or contemplate making track-layer types. I have used every opportunity to inspire greater public enthusiasm in the benefits now being developed by the United States Army for civilian purposes and I feel that we should all do this.

In the case of the Ordnance Department, working as it does day and night, through storms and mud, to develop its tractors, there must be many data relative to the comparative wearing values of various materials, the effect of weight on tractor tracks, etc. If this could be made available to the manufacturers, the expense of their learning what may be known already by the War Department could be avoided.

I think that the farmers will not demand over 4 m.p.h. from a tractor. They are sufficiently accustomed to trucks to demand speed from them, but they will use the tractor for field purposes only. Except for that point in the design of tractors and tanks, it appears to me that the Ordnance Department could utilize the agricultural and manufacturing fields in determining many wearing qualities. This agricultural application may seem visionary, but it might be made. I hope that funds will be made available so that the Ordnance Department can always be in advance of anything used commercially.

H. C. BUFFINGTON:—Ordnance requirements have constituted one of the greatest caterpillar-tractor problems. The industrial tractor business is very attractive, but the company I represent is designing its machines so that, in case of emergency, such parts as are necessary will convert the industrial tractor into the Ordnance Department type. Thus far we believe we have been successful, although there are many problems connected with caterpillar or track-laying tractors that are very vexing, such as differences in the center of gravity when climbing and when going down hills, unit pressure on the ground, resistance to turning, etc. These are very important and must be solved by a compromise that will suit war conditions. The track itself is the greatest problem today. Imagine a heavy railroad train passing over a rail and the rolling-out effect it has upon the rail. This may split the rail, although the train passes over it only several times daily. The track of the caterpillar tractor is subjected to this rolling-out effect continuously during its operation and some tractors operate day and night for weeks. The Ordnance Department is developing the track itself, as well as the tractor, and the engineers of this Society should do likewise.

G. R. PENNINGTON:—As one of the Ordnance Department engineers I wish to suggest a practical means of cooperation between members of the Society and that Department. Frequently those engaged in tractor design have promising ideas which, due to press of other duties or lack of experimental equipment, they are prevented from developing themselves. If these ideas are sent to the tank, tractor and trailer division of the Ordnance Department, they will be studied and, if believed practicable and applicable to military vehicles, this division may be able to carry out the actual development and test of such ideas. Full details of the studies made and the results obtained will be given, so that the originators will become as familiar with the possibilities of their ideas as though they had developed them at their own expense. The Government will at the same time acquire ideas useful in its design work and thus both will be benefited.

DENT PARRETT:—I understand that one of the objects of this paper is to bring out a discussion as to whether it is advisable for the Ordnance Department to develop its own line of engines or use the commercial engines. I have given the matter some thought. It appears to me that a commercial engine should be used. However, the larger size of tractor offers another problem. I know of no commercial firm using engines of a type which would be adaptable to it.

D. M. FERGUSON:—Investigations have been made with reference to the application of regular commercial engines to artillery vehicles. It has been found to date that it is necessary to make certain modifications to suit that application. Some manufacturers are making use of the knowledge gained during the war in the revision and designing of engines to apply to artillery vehicles, but in most instances those designs are merely experimental. Only one or two companies are actually building engines for artillery installation.

LIEUT.-COL. L. H. CAMPBELL:—There is one other point of development, self-propelled caterpillar gun-mounts. We take guns of various calibers, up as high as a 9½-in. howitzer, and mount them on a special form of tractor. The tractor must be of a special design on account of the heavy firing loads we have to care for. In the case of the 9½-in. howitzers, that load will run up in some cases as high as 200,000 lb. With our lighter guns, such as the 75 mm., the load is small, 17,000 lb.

Regarding the cooperation of this Society with the Ordnance Department, before I entered the Department

I had the idea that the Ordnance Department knew it all and that they knew they knew it all. Since becoming a member of it I know its attitude is absolutely the opposite. Within the last few weeks we went out with a special committee of this Society for three days. I learned more from these men about this business than I ever knew before. I worked with ideas that I never dreamed of before. The Society can give us a thousand more of the same kind. We want them.

Regarding the engine proposition, the best thing the Ordnance Department can do is to tie up with some engine builders. If we could establish connections with some manufacturers and let them develop the engine for us, then, as improvements are made, such as another type of valve, they will keep our engines up-to-date. Thus, when twenty years pass and the next war comes, our engines will not be twenty years old. Let us tie up with the civilian manufacturers.

GEORGE W. DUNHAM:—There is a crying need for some workable scheme to provide a consistent and satisfactory line of engines that can be readily obtained for military purposes. I spent much time at Washington during the war and have seen the conditions as they exist, have talked with the men doing the actual work and appreciate the great magnitude of the problems they have to solve. There is still a big work to be done in connection with military motorization.

The latter part of my paper sums up the whole subject as I see it. There is no doubt that the military authorities would prefer a commercial engine if they can get it. If commercial engines are not available, it is essential that the Ordnance Department go in for development. It must have engines suitable for its purposes. The military people might modify their ideas somewhat and some of the manufacturers might modify the structure of the production somewhat, in this way making commercial product for military use an accomplished fact. It is a tremendous task to put anything new into production on short notice, even though there is an unlimited amount of money and effort available. So the Army must have a suitable and preferably a consistent line of designs of engine. The same thing holds true in the case of the complete vehicles. The question is how to bring this about. No mechanism as complicated as motorized equipment can be developed and put into production quickly.

PRESIDENT J. G. VINCENT:—In connection with aircraft and motor-truck problems, everything these officers have said about the possibilities of getting proper engines quickly applies equally and more forcefully to them.

Many of the Air Service officers feel that to be sure of obtaining engines in a time of stress they must commercialize aviation. In some way, engineers must also be developed so that they will be in existence when the call comes for them.

E. A. JOHNSTON:—During the preparations for war, I was called upon to look over many specifications covering tanks and other automotive war equipment. While the company I represented was willing and anxious to undertake all of this war work which it could handle, we were unable to make satisfactory progress because the designs were radically different in many respects from our standard product. It will be difficult to obtain the best possible results if it shall be necessary to depend upon commercial engine designs for war equipment, on account of special requirements.

I believe that tractors developed for agricultural purposes will prove unsatisfactory for war purposes, and vice versa. The automotive industry has great numbers of standard machine tools of all descriptions, but a limited capacity for producing patterns, dies, jigs, tools and fixtures. Consequently, if the War Department could design special equipment to meet its conditions and would also design jig, die, tool and pattern equipment, keeping this equipment up-to-date, it would be a comparatively simple matter for the automotive industry to get into production in a comparatively short time.

A. B. BROWNE:—Experience with the procurement division of the Army demonstrated that vehicles built to Government standards were really the easiest of production, after the period necessary for tooling-up had passed. Although the standardization program advocated at the beginning of hostilities was afterwards abandoned in favor of the utilization of existing types of vehicles, this was very largely due to the fact that the demands of the Army were such that the requisite period of tooling-up for production, and the equally necessary period of testing, could not be permitted. As an alternative, selections were made from among the better type of commercial trucks and such slight modifications were made as were necessary to adapt them to Army use. It is to the credit of the manufacturers that they willingly supplied their working drawings of these trucks for use by separate sources of supply, and thereafter as little difficulty was experienced in obtaining the necessary production as was the case with the Army standardized vehicles. At one period, it seemed that it was about to become necessary to take over all the available truck-producing capacity of this country. A serious drawback to this program was encountered, however, in the fact that assemblers of many different vehicles used the same units in their construction; hence production was seriously limited by the capacity of the various parts makers.

In considering a future program, it should be borne in mind that, when an emergency arises, there is no time in which to develop new models. From five to seven months is necessary to tool-up for a new-model truck, and few manufacturers would have the temerity to place a new model on the market without having road-tested it for from six months to a year. It would seem, therefore, very necessary for the Army to accommodate itself to existing models. Whether these models should be strictly of Army design, or selected from existing commercial designs, is a question for serious thought. Improvement in automotive engineering is so rapid that Government standards would have to undergo continual change to keep abreast of the times. Commercial standards, on the other hand, are kept continually up-to-date, but it should not be forgotten that advancement in design, like any other change, continually renders obsolete many stock parts. Hence, in view of all conditions, it would seem desirable for the Army to maintain as small an equipment of trucks and other automotive apparatus as is consistent with actual necessity, and that a trained engineering staff in each branch of the Army keep continually in touch with the latest developments, so that production might be concentrated on the fewest possible number of types in case of emergency. While it is true that an equal length of time would be required for a second source of supply to tool-up for the manufacture of an existing commercial type, the test period would be obviated and the Army would have immediate advantage of the existing production which, from the fact that it did represent the latest development, would undoubtedly already be of large capacity. This country has dem-

onstrated its wonderful production capacity, and it is in my opinion safe to depend upon this resource with the utmost confidence.

The statement that it is the desire of the Army to keep civilian engineers in close touch with its conditions is most commendable. In the recent war, the most serious handicap imposed upon the automotive engineers was their unfamiliarity with military requirements. They knew the job fairly well, but did not know what the Army needed. If this information was available, it was not placed in possession of those who were engaged in the procurement of automotive material until well into the year 1918. Once known, its effects were immediate, and from June 1 until Nov. 11, 1918, the production of trucks for Government use exceeded the former maximum output by over 400 per cent.

W. S. NATHAN:—I am interested in the engine requirements of the Ordnance Department, especially in the 400-hp. unit. Has the idea of multi-engine equipment been considered? Would it be advisable to take, say, 45 or 60-hp. engines of commercial make and incorporate them in a standard design of tractor; in that way securing reliability and the advantage of being able to utilize commercial equipment?

COLONEL RUGGLES:—One difficulty of having the Government adopt a special design of engine and then make jigs and tools for it is the numbers of jigs and tools we have to have ready. Another very important factor is the keeping of the engine, jigs and tools up-to-date. I believe we cannot persuade Congress to permit us to make jigs and tools every two years. Congressmen would want to know where the old jigs and tools were and why they would not serve. We would be hopelessly behind the times.

We must adopt some engine that is of a commercial type or get the commercial firms to adopt our engine and keep it up-to-date. Enough has been said in the various discussions to indicate what a tremendous problem industrial preparedness is. It is too much for a handful of officers. It is not a problem for military people only; it is the problem of every American citizen. Unfortunately, many people in this country think that if we have men we have an army. That is a mistake. The men are born at least eighteen or twenty years before a war, but the munitions have to be born at the time of the war, because, unfortunately, our country will not consent to carry on hand a large supply of munitions. The best we can hope to do is to have our designs perfected, our plans well thought out, our factories prepared and our engineers trained, so that we can get into war production at the earliest possible moment after the emergency develops.

The problem is too great for the Ordnance Department alone. We hope to present all the problems so that the whole Society will know just what the difficulty is and what progress is being made. It is a question of educating the people to act through Congress to keep the country prepared.

RELATION OF SOLID AND PNEUMATIC TIRES TO MOTOR-TRUCK EFFICIENCY

BY S. V. NORTON

THE discussion is largely in regard to the ability of a truck to deliver merchandise economically under a given set of external conditions. The matter of truck tire equipment is reviewed in the light of recent experiences of many operators and service men. The general functions of tires, securing traction, cushioning the mechanism and the load and protecting the road, are elaborated and six primary and seven secondary reasons given for the use of pneumatic tires on trucks within the debatable field of 1½ to 3½-ton capacity. The deciding factors in tire choice, those affecting time and those affecting cost, are stated and commented upon, the discussion next being focused on how tires affect these factors. Considerations relating to both truck and tire repairs are then reviewed. Separating the field for each type of tire into three parts, the imperative, the economic and the optional, within one of which the operator can reasonably locate his requirements and decide upon his equipment, the specific considerations involved in making this decision are then enumerated. [Printed in the April issue of THE JOURNAL]

DESIGN OF PNEUMATIC-TIRED TRUCKS

BY C. M. MC CREERY

AFTER reviewing the history of transportation, the possible uses of the motor truck are considered. The increased cushioning and traction obtained from pneumatic truck tires accomplish faster transportation, economy of operation, less depreciation of fragile load, easier riding, less depreciation of roads and lighter-weight trucks. These six advantages are then discussed separately and actual facts to substantiate the claims made are presented. Following the detailed consideration of transportation and operation economies, depreciation of loads and roads, the practicability of pneumatic tires is elaborated, and wheels, rims and tire-accessory questions are studied.

The four main factors bearing upon truck design for pneumatic tires are stated and discussed; emergency equipment for tire repair is outlined and a new six-wheel pneumatic-tired truck is described. Five primary changes from present solid-tire design are necessary in the design of the ultimate truck to use pneumatic tires; these are stated in the summary. [Printed in the February issue of THE JOURNAL]

THE DISCUSSION

T. KARGAU:—I was privileged recently to see some of the original data used by Mr. McCreery in his paper His associates were devoting much time to an analysis of the performance of pneumatic tires which they distributed to replace solid tires. In several cases the Goodyear Company has substituted pneumatic for solid-tires with the intention of running a six months' test, one-half or one-third of each fleet being equipped with pneumatics. After one month the owners of the fleets in many cases would not allow the tests to continue, but changed over all trucks to pneumatic tires because they could not afford to let the others run on solid tires. The costs in all cases were kept according to the National Standard Truck Cost System. When I saw some of the figures I

could scarcely believe them. Occasionally a 30 per cent saving of gasoline was shown and a few instances were given where perhaps 50 per cent of the oil was saved. Owners have perhaps over-estimated the mileage in some cases, but there is little doubt that many of these tires have run more than 20,000 miles.

It appears to me that Mr. Norton is absolutely correct in making the statement that the pneumatic field is open and that two years hence everything up to the 2-ton size will be pneumatic-equipped. There are some serious objections to what is being done with pneumatic tires by certain companies at present. There is a tendency, at least among salesmen, to place the speed limit on pneumatic tires at about 40 m.p.h. The average truck on the market today, if it were traveling 40 m.p.h., would require service, emergency and a few other brakes to hold it if it had to be stopped quickly. That it is the one outstanding feature regarding changing to pneumatic equipment; the present brake equipment will prove inadeqate at high speeds.

A MEMBER:—What experience have the users had in keeping the pneumatic tires on trucks properly inflated? What effect do properly or improperly inflated pneumatic tires have upon the steering apparatus?

O. C. BERRY:—How does Mr. McCreery explain a seeming discrepancy in the evidence. Tables II and III show that when the trucks were equipped with pneumatic tires they used less gasoline and less oil than with solid tires. Granting that the use of pneumatic tires will result in the truck requiring less power when running at an ordinary speed on a good road, it may nevertheless be pointed out that it will require an equal amount of power to start the load or to get through a very difficult piece of road; so that, no matter whether pneumatic or solid tires are used, the trucks must be equipped with engines having the same power capacity. The pneumatic tires will therefore result in the standard truck engine running under a lighter load, or at a higher speed, or both.

My experience with engines indicates that they do not use less oil at light than at heavy loads. If the oil used be expressed in pounds per 1,000,000 revolutions, or in pounds per truck mile, the amount used will not vary very much as the speed of the engine is changed, and will not decrease as the load is decreased. It is therefore easy to understand why the pneumatic tires would cause the truck to run more miles per gallon of gasoline, but hard to account for the use of less lubricating oil, unless there is some other factor involved that is not indicated in the paper. In view of the extreme difficulty that is always encountered in controlling the running conditions in road tests, I therefore inquire whether in the opinion of Mr. McCreery the tests were checked sufficiently to substantiate the fact that the results reported in Tables II and III are characteristic and that pneumatic tires do result in the use of less lubricating oil.

N. B. BURKNESS:—I know of a case where seven first-class 2-ton trucks equipped with solid tires were re-equipped with pneumatic tires. The speed limit in the locality was 28 m.p.h. The seven trucks exceeded that limit invariably.

A MEMBER:—If the standard solid-tire equipment is changed to pneumatic, the load capacity of the truck is increased invariably. What reasons can be given for this?

W. G. WALL:—What data are available as to the comparative ability of a truck equipped with solid and one with pneumatic tires, to go through rough roads and mud? I observed some interesting tests made about three years ago, which I believe Colonel Slade conducted. He had four or more different makes of truck, two of each. One of each make was equipped with pneumatic and the other with solid tires. The pneumatic tires performed remarkably well on all the good roads. There was no question that the pneumatic tire seemed to come out ahead in all the good-road tests. I was rather surprised, however, when the ability of these tires to go through mud was tested. The ground they were pulling through was rather soft, and the wheels sank in from 10 to 15 in. Ability was shown by the distance they were able to go without stalling the engines. That distance seemed to be exactly the same with pneumatic or solid tires. The various makes of truck went different distances, but all became stalled eventually, so it was difficult to judge whether there is really any difference in power required between the pneumatic and the solid tires, in pulling through mud. During the tests both seemed to sink down the same distance and both showed that they required about the same amount of power to get them through.

PRESIDENT VINCENT:—Did both the trucks have the same gear ratios?

MR. BURKNESS:—The ratios were the same. The solid tires were 36 by 6 in. and the pneumatic 38 by 9 in.

CHARLES GUERNSEY:—I believe that the analysis of this problem as presented by these two authors will be of considerable benefit. The matter of steering was mentioned in Mr. McCreery's paper. It has been our experience that trucks equipped with pneumatic tires steered considerably harder, even when the tires are highly inflated, than the same trucks when equipped with solid tires. I agree with the authors in their statement that it will be necessary to design trucks specially to meet the new conditions created by the use of pneumatic tires. One of the most important advantages of the pneumatic tires is the increased speed which they permit. To realize on this advantage it is necessary to design the truck to fit the conditions.

Mr. McCreery prophesies a material saving in weight when trucks are designed solely for pneumatic tires. It is my belief that, while weight may be saved at some points, it must be added at others and that, given the same standard of engineering, the pneumatic-tired truck will weigh practically the same as the solid-tired truck of the same capacity.

Some time ago I made an analysis of practice in the design of front-axle centers and found that it was common to use stresses in passenger-car design which were higher than the stresses in solid-tired truck design in the ratio of 10 to 8. This would indicate that all load-carrying members might be made 20 per cent lighter in the case of pneumatic tires. As a matter of fact, however, the size and weight of a number of these load-carrying parts are determined by manufacturing conditions rather than by stresses. It would appear, therefore, that we can expect a saving in weight of something less than 20 per cent of the load-carrying parts, such as axle centers, spindles, rear-axle housings and spring shackles.

On account of the higher speed of pneumatic-tired trucks, it is necessary to increase the gear ratio materially to keep the engine speed within reason. This requires that larger engines be used. These large engines in turn necessitate more radiation, heavier clutches and transmissions and propeller-shafts. In fact, the power line will need to be made heavier all through. The in-

creased weight of the heavier engine, transmission, clutch, etc., will more than offset any saving in the axle load-carrying members. Weight can undoubtedly be saved by the substitution of lighter materials of construction, but this change is not affected by the tire situation.

As regards the possibilities of various sizes of tires, I believe that neither of the authors will take exception to the statement that tires 44 by 10 in., or larger, cannot be satisfactorily used in any great number of cases. It would therefore appear that the possibilities of dual pneumatic tire equipment or the six-wheeled truck, mentioned by Mr. McCreery, need to be watched.

G. L. LAVERY:—The subject of steel wheels is pertinent to the matter Mr. McCreery speaks of, but it has not been mentioned by him in his remarks on pneumatic tires for trucks. Much weight can be saved on wheels for pneumatic tires compared to what is required with wheels for solid-tired trucks. Solid-tire wheels must be made very strong, much stronger than would ordinarily be necessary, as, in cases where the tires are worn down to the tire band, the load has to be carried on the wheels themselves to bring the load home; with pneumatic tires the wheel can be made as light as it can be run when cast in the foundry. In the case of the 38 by 7-in. demountable wheel the weight of the wheel itself, with the hub cast integrally with the wheel, is about 72 lb. less than the weight of the demountable rim that surrounds it. The solid-tire wheel of the same capacity will weigh from 260 to 300 lb.

The brakes on the "ultimate" truck will need to be of a different character from that of those now in use, because the wheel diameter for pneumatic tires has been established at 24 in., irrespective of the size of tire. The inner diameter of the brake-drum used at present on the 5-ton truck is larger than the diameter of the pneumatic-tire wheel and, in designing the new type of brake-drum the outside diameter of the wheel should be considered.

F. J. SULLIVAN:—In using pneumatic tires is it necessary to have longer bearings on the wheels owing to the thrust produced in turning corners? Is it not a fact that the larger tires are subject to trouble caused by the sidewalls cracking because of going through deep ruts? Why do the smaller 36 by 6-in. or 38 by 7-in. cord tires stand up better?

L. C. FISK:—Has Mr. McCreery noticed any difference in bearing performance in the trucks that have been making the long haul between Akron and Boston? Have the bearings given trouble or has their performance been better than might have been expected if the trucks had been equipped with solid tires?

E. T. BIRDSALL:—I know of a well-known truck manufacturer who never used any pneumatic tires until last year. The company had been exceptionally free from front-spindle trouble. Its front axles and spindles had been made very heavy and of a good grade of alloy steel. Since its customers have put pneumatic tires on some of the trucks a number of front spindles have broken. It seems to me that this is due primarily to the increase in speed; it would appear that when the speed of the trucks is doubled, the road shocks are more than doubled. I have no accurate data in regard to that. In general, I believe that the pneumatic-tired truck is the coming truck. I have ridden on the six-wheel truck, and I am convinced that it has good possibilities.

At present we are thinking mainly of freight-carrying trucks, but I believe that one of the largest fields that is about to be developed is that of the large omnibus. There is no question that we can operate omnibuses in congested districts better than we can cars on rails. I say that from a fifteen-year experience in the street railway business, and about the same or more in the automobile business. For the large omnibuses carrying thirty or forty passengers, the six-wheel idea offers many advantages. At the Goodyear plant in Akron we rode along smoothly over rough roads on six wheels, although we were sitting on sandbags and the springs were none too good; the performance was really wonderful. If anyone has mentally compared changing those 48 by 12-in. tires, and the 36 by 8-in size, and can imagine being out in the country with one or the other to fix, there would be no question as to choice.

E. A. BELL:—It might be of interest to know what the actual experience of my company has been with the pneumatic tire. We had five trucks. They were operating in Australia and were originally fitted with pneumatic tires. After two years of operation we found we had had to renew the rear axles and bearings twice. I decided to change the bearings. The size of the tires, when fitted, slightly raised the ratio. We found after twelve months' operation that we were actually 8 to 9½ per cent better off regarding gasoline consumption.

Regarding the steering, we found it undoubtedly easier. As to bearings, after two years' further operation with the pneumatic tires, we had no need to renew a single bearing in the five rear axles. Previously, with solid tires we had had two sets of bearings.

We found it necessary to use what we call security bolts on the tires in traveling on rough roads; otherwise we were continually ripping the valves out. We used the beaded-edge tire.

In reference to the remark in Mr. McCreery's paper that it is very rarely found that the pneumatic tire goes flat suddenly, our experience has been that if it gets a puncture, the tire is flat before it goes many feet farther and in almost every case it requires a new section. In fact, when the tire goes flat, it goes very quickly. Those have been our actual experiences in Australia.

E. E. WEMP:—We have very recently developed, and are marketing a 1½-ton speed truck. Our experience thus far has shown a very decided advantage in the use of pneumatic tires over solid-tire equipment. We have been able to improve the gasoline economy, and the general wear-and-tear on the chassis has been apparently materially reduced on account of the better suspension.

In the development of the job it was our purpose to hold the chassis weight down, and very careful consideration was given to details of construction whereby the weight would be reduced without sacrifice of strength. The reduction of weight was accomplished very largely by careful design and without resorting to other than conventional materials. In this regard it is our opinion that the weight can be reduced considerably more by the judicious use of aluminum, in place of malleable castings, cast iron and the like. After listening to the paper and the discussion on the use of aluminum in axles, and particularly in wheels, it would seem that there is a possibility of making a considerable reduction in weight by the use of aluminum for those parts. In general, I believe the industry is becoming aware of the importance of reducing chassis weight to the minimum, and that great progress will be made in the near future toward the accomplishment of this purpose.

Another point which I believe will stand investigation on the part of engineers is the weight of commercial-vehicle bodies. It would seem in looking over conventional body construction that less progress has been made in the art of body design than in any other element of chassis development. The bodies of today are built along the same lines as those of the preceding decade, and it

would seem that the standard body allowances as established by the National Automobile Chamber of Commerce will require a revision in view of the development of high-speed pneumatic-tired vehicles. After considerable investigation along these lines it would appear that the proper selection of body materials and the disposition of the materials, so as to obtain maximum strength with minimum weight, will make it possible to reduce body weights, particularly in the smaller sizes, from 20 to 30 per cent.

The problem of ample braking capacity is one of the most serious ones encountered in the design of the high-speed pneumatic-tired truck. The kinetic energy of the vehicle increasing as the square of the velocity makes the problem of braking one that is most pertinent.

The question of final-drive on comparatively light high-speed trucks is one which can be given a great deal of attention. At present chassis of this character having a capacity of ¾ ton are ordinarily equipped with a plain bevel-gear type of axle, and the necessary ratio is obtained in one reduction. When the capacities are increased to 1½-ton, it is rather hard to obtain the necessary ratio with a bevel-gear drive. Much thought is being given to this problem, at least in an experimental way, whereby the maximum ratio obtainable in a bevel-gear drive has been very considerably increased. It may be that with further work in this direction the solution of the rear-axle problem for a vehicle of 1½-ton capacity will lie in the bevel-gear type. It might be possible to accomplish the results by a reduction at the rear end of the transmission and a second reduction through the ordinary type of bevel-gear axle. This would permit a large variety of speed ratios within the range of bevel-gear sizes commercially available at this time. It would incidentally reduce the weight of the axle, which naturally is an advantage inasmuch as the mass of the axle in itself is unsprung.

I was very much interested in the description of the six-wheel-drive truck, having a capacity of 5 or 6 tons and mounted on 40 by 8-in. tires, both front and rear. This design would appear to be a step in the right direction for solving the problem of heavy-duty pneumatic-equipped trucks. Undoubtedly there are many problems in the design yet to be solved, but fundamentally the idea appears to be sound and it may be that in the final analysis the cost of the bevel-axle equipment in the rear, together with smaller wheels and tires, will compare favorably with single-axle construction, necessarily of greater weight and cost. From the standpoint of tire replacements on the road the advantage of a smaller tire is obvious.

The next few years are bound to see tremendous development in the use of pneumatic-equipped trucks.

F. D. HOWE:—The time of changing a tire was given as 30 min. Was this for a demountable or for a detachable tire? Can a tire be detached and a new one installed in 30 min.?

C. M. MCCREERY:—One point was brought up regarding solid tires and pneumatic tires stalling under approximately the same conditions. The remedy for that, as I see it, is a limitation of both the motive power and the gear ratio. In other words, our rear tires have been stuck many times; we have had cases where we had insufficient power to pull out.

As to the matter of using lighter parts in trucks on which pneumatic tires are used, theory is one thing and actual practice another. Theory would naturally indicate that, due to the higher speeds, stronger and heavier parts are necessary, but in the absence of any development along this line we undertook to use lighter parts, making use of standard chassis parts. One of the first things we did was to use a 3½-ton truck frame for 5-ton work, much against the wishes of the original designer of the truck. We operated that truck for 60,000 to 90,000 miles under typical demonstrating conditions with no effect on the frame whatever. We then went down to a 2-ton frame, in the face of constant warning, and that 2-ton frame is in service now; it has gone from coast to coast. We have noted nothing that indicates trouble with the frame.

I believe that the same thing applies to the steering apparatus. Pneumatic tires have more ground contact than solid tires, but there is an appreciable amount of resiliency that absorbs ground friction. I think it could be shown theoretically that steering ought to be harder. As Mr. Bell says, the trucks do steer easier. I do not know why. On the Boston run our drivers are able to make turns safely that they are not able to make with solid tires.

As far as the bearings are concerned, it has not been our experience that we need to change the bearings at all. Of course, much of the status of information on this subject is due to lack of research on the part of the bearing companies. The roller-bearing companies have taken the matter up in the last two or three months. From the preliminary investigation of one bearing manufacturer the solid tires require 20 per cent larger bearings than the pneumatic tires require.

As far as the other parts of the motor truck are concerned, there has been very little thought given to what is necessary, for the reason that most of these truck manufacturers have not taken the subject seriously and have waited.

I am very much inclined to agree with Mr. Wemp in the matter of body design. The time necessary to remove a tire is difficult to estimate. I favor the demountable rim. With some of these it is easily possible to change in less than 30 min. I think that has been demonstrated by numerous truck operators. With various detachable tires truck operators take from 1 to 3 hr. to change them, depending largely upon the pump equipment used in connection with the tire. The air-pumps have been one of the bad features.

MR. SULLIVAN:—To put my question more clearly, the Goodyear Company had four wheels driving and two steering; was that to improve the riding quality or to ease the strains on the walls of the tire? Using four driving tires the walls were reduced in size and not so apt to tear.

MR. MCCREERY:—We believe that the larger size pneumatic tires are not as practical as four smaller tires. I mean specifically that the 48 by 12-in. tire, which is used on the 5-ton truck and cannot carry more than the others do, is too heavy for one man to change on the wheel. It costs more than the average truck operator can afford to pay. Moreover, it raises the center of gravity to a point that, while not at all dangerous, is not desirable. It necessitates a radical change in gear ratio.

We are able to equip this particular six-wheel truck with 8-in. tires, which are very much lighter in weight. We can reduce the weight approximately 800 lb. below that of a standard solid-tire 5-ton truck. We can use two axles, four wheels and four brakes of 21-in. diameter, in place of two axles and two wheels, and that whole equipment costs no more than the corresponding parts of a standard solid-tired 5-ton truck. That answers the question of brake capacity. We are able to stop the truck in 60 ft., from a speed of 25 m.p.h. Moreover, we get easier riding, a saving of the load itself, and a saving of the road.

A TRACTOR ENGINE TEST

BY C. A. NORMAN AND B. STOCKFLETH

A FOUR-CYLINDER 4 by 5-in. truck and tractor engine, designed for either kerosene or gasoline fuel and having the very low volumetric compression ratio of 3.36, was used. Only by suitable adjustments was it found possible to make it show a fuel consumption as low as 0.67 lb. per b.hp.-hr.; but with a slight variation in power and only a different carbureter adjustment the fuel consumption at 600 r.p.m. increased to about 1.2 lb., or 70 per cent, emphasizing the importance of knowing what constitutes the best engine adjustment and of disseminating such knowledge. The engine and its dimensions, the experimental apparatus and the method of testing are fully described and discussed, the results being presented in charts showing performance curves. These are described, analyzed and the results interpreted. [Printed in the February issue of THE JOURNAL]

THE DISCUSSION

O. C. BERRY:—What jacket-water temperature was maintained in these tests and what kind of fuel was used? The less volatile fuels require a much higher jacket-water temperature and more heat in the mixture to get good carburetion, than do the high-grade gasolines.

In comparing these results with the Purdue tests, it will be noticed that the curves are drawn to different coordinates, the lean mixtures being represented at the right-hand end of these curves and at the left-hand end of those in the Purdue paper. In these curves the chemically perfect mixture is obtained with 14.77 lb. of air per lb. of gasoline.

We are threatened with a shortage of fuel, and as Mr. Kettering expresses it, this is the one cloud on the automotive horizon. If we are to meet this situation in such a way that the automotive industry will continue to grow in the future as it has in the past, we must solve several problems.

In the first place, we must produce an engine that will use the fuel more efficiently, as has been very clearly pointed out in this paper. In this connection I mention the desirability of having the carbureter designed so that a complete adjustment can be obtained by a device on the steering post of the car. The device should be more than a mere "choke," it should make the mixture leaner or richer by the same percentage through the entire range from no load to full load. The value of such a device can be pointed out in this way. If a carbureter is adjusted so that it will give a rich enough mixture to start the engine and cause it to run nicely when it is cold, the mixture will be too rich when the engine warms up. Although without accurate data on this point, I would estimate that this excess fuel will often amount to 30 per cent. In other words, without a device of this kind one may be forced to waste one-third of all of the fuel used.

I have used a device of this kind for a number of years and would not willingly be without it. I start out with a good rich mixture and after I get well started I make the mixture continuously leaner until the engine commences to lose power. I then make the mixture alternately a little richer and a little leaner until I find a mixture that will give almost but not quite the full power. This is the mixture for best general performance in that it will give almost the maximum power and at the same time almost maximum efficiency. In case the engine heats up later or the day gets warmer, I can readjust the carbureter while driving. The operation is not difficult, is in fact enjoyable and it results in a marked increase in the miles per gallon of gasoline.

To be successful, a device of this kind must be so designed that the richest mixture obtainable is just barely rich enough to allow a cold engine to run nicely, and a separate device must be supplied for flooding the carbureter to start the engine. This is necessary to make it fool-proof. A large percentage of automobile drivers will flood the carbureter if such a thing is possible. If designed as suggested, the unthinking driver will get along as well as he could with any other fool-proof carbureter, and the skilled driver will be able to obtain ideal results.

Important as increased economy is, the fuel problem cannot be completely solved in that way. We must extend the fuel supply. The most obvious way to do this is to include in the engine fuel a larger part of the crude petroleum, or more "heavy ends." This would however result in two things:

(1) The poor carburetion resulting from the heavy ends would lead to excessive engine trouble and maintenance costs
(2) The heavy ends in the fuel would result in a violent kerosene knock

Mr. Kettering and the other men working with him have pointed out that the kerosene knock, or detonation, can be eliminated by producing a proper fuel blend. Alcohol, benzol and some other fuels, when added to the petroleum products, will do away with the knock entirely.

The staff of the Purdue Engineering Experiment Station and many other investigators are striving to develop a carbureting system capable of handling the less volatile petroleum products. We will soon know just how far it is possible to go in that direction, and what the limiting factors are. We feel confident that the limit has not been reached as yet, and even hope to see the time when we can carburet all of the more fluid petroleum products. In conjunction with the cracking processes of making gasoline, this may make it possible to convert petroleum into engine fuel, lubricating oil and petroleum coke. The alcohol and benzol added to this petroleum fuel to produce a proper blend will again add to the volume of the available fuel, so that there is still reason to hope that the fuel problem can be solved, at least for the immediate future.

C. A. NORMAN:—The distillations are given in the paper. In getting better efficiency, it is desirable to have the steering-post carbureter adjustment. If a carbureter gives a rich enough mixture to start nicely when the engine is cold, when it warms up the mixture is too rich. We have no accurate data on that point. It will amount to 30 per cent in cool weather; in cold weather, to more than that. This means the throwing away of part of the gasoline. With a steering-post adjustment, the engine can start with a rich mixture and warm up; if the mixture is richer than necessary, it can be made leaner. It can then be adjusted to a point just below the highest power, the point best suited for the best performance.

In a large way, there are two problems involved in

solving this fuel question. One is to develop a carbureter that can utilize the heavier oil products. But these heavier petroleum products produce a heavy knock. As has been pointed out by Mr. Kettering and others, the solution of this problem seems to be through the fuel blend, using petroleum, alcohol, benzol or some other fuel of that character, introduced to do away with the detonation.

J. H. SHOEMAKER:—Have any engineers tried two-spark or multiple ignition? As an instance, during the war a seaplane was unable to rise from the water; a two-spark ignition was installed, which gave an increased number of revolutions per minute and the additional power needed for rising. I do not know whether that gave greater fuel economy.

W. G. WALL:—Professor Berry's remarks suggest how much fuel is lost, after engines become heated, by not shutting off the excess gas. Would it not be feasible and possible to attach a thermostat in the water line and connect it to the needle-valve of the carbureter so that, as the engine heats up, the amount of gasoline will be cut down? The temperature of the water in the water-jacket bears only a comparative relation to the temperature of the engine, although such a relative change from a cold to a hot engine, which would operate the thermostat, could readily be used to cut off a part of the gasoline supply. Has this method been used?

F. D. HOWE:—I recently received a carbureter that has a thermostat in the gasoline bowl. The viscosity of the fuel changes with its temperature, so the fuel temperature is what we need to measure. It looks promising to me.

CHARLES GUERNSEY:—Professor Berry recommended the use of steering-post control to regulate the quality of mixture in accordance with the needs of the engine. We have tried this construction and have been forced to abandon it. We at one time used a carbureter which was fitted with an adjustment operated from the steering column. It did not work out satisfactorily in truck use. The driver would set the adjustment to the rich-mixture position for starting and forget to reset the adjustment until the engine began to labor heavily.

Both Professor Berry's and Professor Norman's studies have shown that it is possible to operate an engine smoothly within very wide limits of mixture proportion. The result was that these trucks were operated a great portion of the time away over on the rich end of the mixture range, resulting in high gasoline consumption, heating and serious carbon deposits. I am inclined to agree with Mr. Wall's suggestion that a thermostat be used in such a way as to enrich the mixture when the engine is cold, coming down to the standard adjustment after the engine has reached the normal temperature.

MR. SHOEMAKER:—Would it not be practicable with such a device to have it held in the lean-mixture position by a spring, so that the driver would be forced to hold it long enough to get the engine up to its power?

PRESIDENT J. G. VINCENT:—That has been found desirable in many cases; otherwise, the engine would run on too rich a mixture, and accumulate compounds in the crankcase that are not wanted there. The question was asked whether two sparks might not aid in economy. Would the engine run with a leaner mixture if two sparks were used?

ROGER CHAUVEAU:—That depends largely upon the shape of the cylinder. We found, in aviation, where we used overhead valves, that two sparks had very little effect. On the other hand, in a T-head cylinder if the spark-plugs are placed in the very best location, from 20 to 25 per cent better fuel economy can be obtained. In an L-head cylinder this runs from about 6 to 12 per cent. There are other features in the two-spark ignition which are of advantage. It is possible with two-spark ignition to run the engine with less spark advance, which tends to prevent overheating and partially overcomes the pinking and kerosene knock.

PRESIDENT VINCENT:—What is the effect on the power?

MR. CHAUVEAU:—Two-spark ignition will increase the power, according to the shape of the cylinder-head, from 10 to 20 per cent.

T. KARGAN:—What is the effect on slow-speed engines?

MR. CHAUVEAU:—The speed of the engine counts, of course. If it is a question of an engine speed of 600 to 800 r.p.m., the effect will probably be approximately one-half of the figures mentioned above, as these figures were based on engines running from 1500 to 2000 r.p.m.

E. T. BIRDSALL:—In regard to the control of the carbureter from the steering-post, some time ago, in my enthusiasm to get the correct mixture I installed a Master carbureter on my car. After that experience I am through with attempting to give the driver control of the mixture. I became so tired of juggling that lever that I took it off and, although I got better results, life is too short for such a thing. If that is too much trouble for me, with all my enthusiasm, it will not appeal to a truck driver. My contention for years has been that the only way to put a carbureter on is to set it as nearly right as possible, and then dip the whole thing in solder so that the driver cannot change it.

In regard to economy, I have been making some experiments in crankcase dilution, which is, of course, closely allied to economy. With the choking method we have been putting all kinds of fuel into the crankcase. On my own engine I have aluminum pistons. I can tell very closely the stage of my crankcase dilution by the piston slap. I want to avoid that, but I want to be able to start promptly in cold weather and so I have been trying out various primers. Last November I put on a type of primer that boils the gasoline. The level in the primer chamber is the same as that in the carbureter. I have abandoned the use of the butterfly choker. I have found that with this device I practically eliminated crankcase dilution at least for three months. It is running now, and the pistons have not notified me as yet of any excess of gasoline in the crankcase. I also get less back-firing when the engine is cold.

This device, if operated when the engine is not running, produces a vapor or fog which does not condense. It simply floats off into the air, and can be lighted with a match. I believe there are two or three of these devices on the market and they should eliminate probably 75 per cent of the crankcase dilution and also give better economy by not wasting gasoline in the crankcase.

Going back to the steering-post adjustment for the ordinary truck drivers, which applies also to 90 per cent of the ordinary passenger-car drivers, I am absolutely against it. They will not operate them properly, if they operate them at all. The more adjustments the driver has at his command, the poorer is the economy obtained from the truck.

PROFESSOR NORMAN:—The questions have been very largely answered by other speakers in the course of the discussion. I shall therefore mention only a few points.

The temperature of the cooling water was kept as

(*Concluded on page* 102)

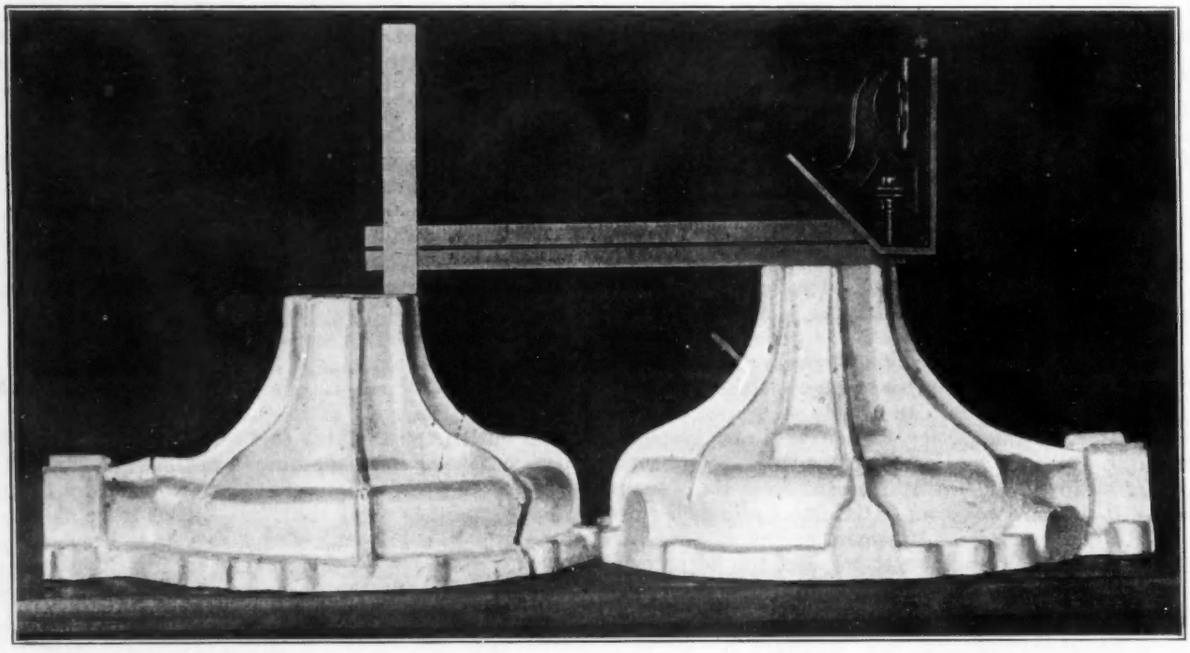
Developments in Alloyed Aluminum

By R. E. CARPENTER[1] (*Member*)

INDIANA SECTION PAPER *Illustrated with* PHOTOGRAPHS

THE casting of alluminum alloys is to a certain extent an art. The writing of the technology of this particular art was undertaken by a group of men in our laboratory, selected because of their particular training and experience, and some day this art will be reduced to a science. In 1919 tremendous strides toward that end were made. The organization embraces the technical department of the Aluminum Manufactures, Inc. Its functions include metallurgical research and development, manufactural or process research and development and such engineering and designing as are necessarily involved in the development of new products which require designing, testing and possibly the working out of new methods of fabrication.

Prior to the assembling of this particular organization, we had, of course, like all other founders, a general knowledge of the chemical constituents of our alloys and had also determined that certain practice with reference to molding and pouring produced satisfactory usable castings. The effect, however, of slight changes in chemical constituents upon the standard alloys generally used at that time, had not been considered to any extent. Like almost everyone else, we had used almost exclusively the standard 92-8 aluminum-copper alloy. Our first task therefore included a careful study of the effect of slight changes in the percentages of the constituents, as well as of the addition of other metals. This careful study was undertaken particularly from the metallographic standpoint. By the microscopic examination of the dispersion of the alloyed elements, it is possible to prescribe new alloy mixtures and predict their properties. As progress in alloy development is made, the field of new and unexplored metals and elements will become narrower and improvements will lie more and more in the modification of the arrangement and treatment of metal mixtures whose composition is known to us, rather than in the discovery of new mixtures.



CHANGING FROM ONE ALLOY OF ALUMINUM TO ANOTHER REDUCED THE HEIGHT OF A DIFFERENTIAL CARRIER ½ IN. AND ALSO INCREASED ITS STRENGTH 4000 LB. PER SQ. IN.

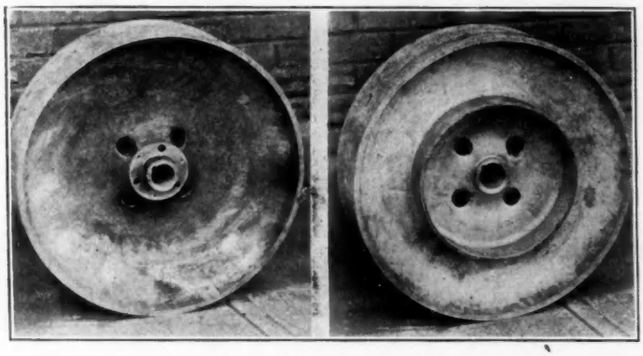
PRODUCTION OF NEW ALLOYS

The first important result of our alloy development program was the production of the Lynite No. 112 alloy, which is the original 92-8 mixture known as No. 12 (S. A. E. No. 30), with slight additions of other metals. The desirable casting characteristics of the alloy are not materially changed from those of the earlier one, but a decided improvement in the physical properties is effected; in fact, there is an improvement of approximately 15 per cent. Alloy No. 112 was used extensively in the Liberty engine program. The minimum standards used by the inspection department of the Government to enable a few of the smaller foundries in the country to handle some of the business, allowed castings to pass which under test developed only 16,000 lb. per sq. in. tensile strength with 1 per cent elongation. Even at this low mark, many aluminum castings did not meet the

[1]Manager, Lynite Laboratories, Cleveland.

specifications. Our company accepted the minimum standard set by the specifications and the No. 112 alloy enabled them to be met with entire satisfaction. Only three test-bars taken from all the castings produced, failed to attain this minimum tensile strength, and these failed by only a few hundred pounds. A great many of them ran as high as 24,000 lb. per sq. in. While the casting characteristics of this particular alloy are only sightly different from those of the standard 92-8 mixture, to maintain the higher properties a close control of the added constituents must be maintained. Until recently the bulk of our sand castings were produced from No. 112.

The next improvement, which has recently been made, is our No. 112-B. This alloy will develop on an average between 19,000 and 21,000 lb. per sq. in. tensile strength, with an elongation of from 1½ to 2 per cent in standard test-bars. Even with these physical properties, aluminum is only comparable with an ordinary grade of cast iron except with respect to elongation. To develop a better engineering material, during the past year some 1000 or more alloys covering compositions of aluminum-copper, aluminum-zinc and aluminum-zinc-copper, with still other added constituents, were made and tested. As a result of this research our present high-tensile-strength alloy, No. 145, was evolved. This has an ultimate average tensile strength of 27,500 lb. per sq. in., with an average elongation of 4½ per cent. The combination of these two desirable qualities provides an excellent casting alloy. It makes possible the use of aluminum alloys in parts heretofore made of malleable iron and enables engineers to consider the reduction of sections in their designs to the point where the only limit is the ability to pour satisfactory castings in molds. The specific gravity of this alloy is only 2.92. Alloys which have a specific gravity exceeding 3.00 are usually high in zinc and have not



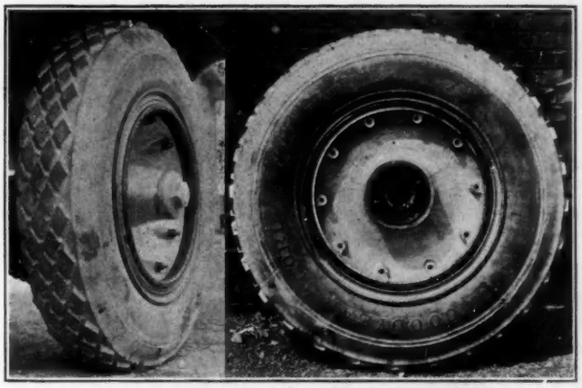
ALUMINUM-ALLOY WHEELS FOR SOLID TIRES

been found very reliable. The physical properties of the standard Lynite casting alloys are shown in the accompanying table:

AVERAGE PHYSICAL PROPERTIES OF STANDARD LYNITE ALLOYS

Lynite Alloy number	Tensile Strength of Sand Castings, lb. per sq. in.	Elongation in 2 in., per cent	Impact value, ft.-lb.	Specific Gravity
112	20,000	1.5	0.95	2.85
112-B	21,000	1.5	0.95	2.86
145	27,500	4.5	2.00	2.92
109	20,500	0.5	0.80	2.89
122*	28,000	0.5	....	....

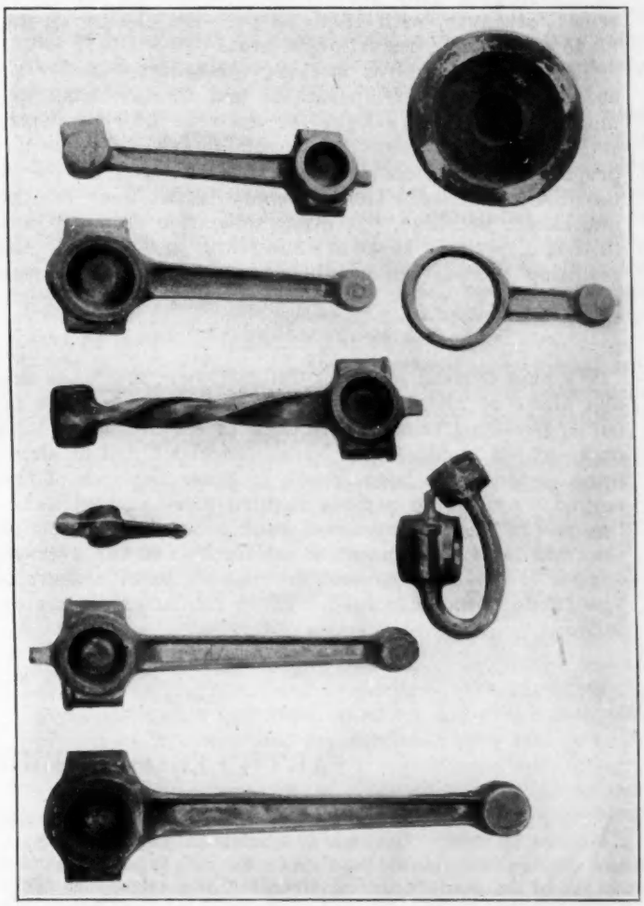
*Cast in permanent mold.



PNEUMATIC-TIRED TRUCK WHEELS MADE OF AN ALUMINUM ALLOY

The application of the No. 145 alloy to parts which heretofore have been considered too highly stressed for aluminum, led to many trials in differential carriers, rear-axle housings, truck and passenger-car wheels and other parts where the reduction of the unsprung weight is desirable.

Perhaps the most sensational step in our alloy development program has been the evolution of a forging alloy. While I am not prepared to say that at some future date we may not present to the automotive industry crankshafts and camshafts made from an aluminum alloy, we



PARTS PRODUCED FROM A FORGING ALLOY OF ALUMINUM

A Passenger-Car Wheel of the Disk Type Made from an Alloy of Aluminum

do expect in the immediate future to offer an aluminum alloy connecting-rod which will withstand the service required of it and assist the manufacturer in cutting down the reciprocating weight as well as in reducing rotating masses and bearing pressures. The physical properties which we have thus far been able to secure in the forging alloy are 55,000 to 65,000 lb. per sq. in. tensile strength, with 18 to 22 per cent elongation and 38 to 40 per cent reduction in area.

The process involves working the material under accurately controlled temperatures and careful heat-treatment after forging. Thus far the rods which we have tested have been found very satisfactory. We are not prepared to make the definite statement that it will be possible to eliminate the customary babbit liner for the crankshaft bearings, but every indication so far points in that direction. If we are successful in doing this, the resulting economy in weight and cost will be apparent to everyone.

Aluminum Pistons

We have learned much in the past year about the use and abuse of aluminum pistons. We and a number of our engineering friends have come to the conclusion that many of the troubles that have been attributed to aluminum pistons have been caused by other features of the engine. Aluminum pistons require more careful handling and fitting than cast-iron ones, but there is no doubt they can be used with entire satisfaction in the average engine, if the designer and the manufacturer observe a few fundamental principles. These fundamentals are as follows:

(1) Careful attention to the oiling system, to prevent a superabundance of oil being thrown into the cylinder
(2) The cylinder walls should be properly finished so that they are smooth and round, and the cylinder should be designed and its walls constructed so that they will continue to be round
(3) The piston should be properly finished and held within close limits as to diameter and clearance in the cylinder
(4) The piston should be designed so as to provide satisfactory bearing surfaces, proper location of and support for the wrist-pin bosses, and no superfluous ribs or uneven sections to cause distortion

I do not wish to infer that aluminum pistons must be made with gage-like precision, but to state definitely that in fitting aluminum pistons more care must be taken than with cast-iron pistons, and closer limits must be maintained.

Aluminum alloys, we all know, have a greater coefficient of expansion than cast iron; therefore the maximum size that a piston may attain under operating conditions must be reckoned with and the high limit of piston size when cold held accurately within a given figure. The tolerance given the production department must be taken in the opposite direction, with the understanding still in mind that if this limit is carried too far a tendency toward piston slap will result, but I wish to say very positively that aluminum pistons can be fitted sufficiently freely to allow the running of the engine at any speed within the driving range of the car without piston slap, and with many beneficial results in the smoothing out of the engine performance, whether with a four, six or eight-cylinder engine. We expect that within three years not only will the majority of passenger cars be using aluminum pistons, but that the use of these pistons, which embody extremely desirable thermal qualities, will have extended to the truck and tractor engine field.

By way of illustrating the point about thermal qualities, attention is called to the pistons used in the Liberty engine. We made more than 600,000 of these pistons during the war. They finished up to a weight of approximately 3 lb. If a cast-iron piston had been provided, containing the same capacity for heat conductivity that was embodied in the 3-lb. aluminum piston, the cast-iron pistons would have weighed in the neighborhood of 22 lb. This statement can be very quickly checked by the fact that heat conductivity is a question of volume rather than of weight, and aluminum has at least three times the heat-conductivity properties of cast iron. A cast-iron piston, therefore, to have the same capacity for heat dissipation as one of aluminum, would have three times the volume of metal which, if cast iron weighed the same as aluminum, would involve a 9-lb. piston. However, since cast iron weighs over 2½ times more than aluminum, volume for volume, it is seen that a piston providing the same thermal qualities would have weighed about 22 lb.

ARTICLES ON AERONAUTICAL SUBJECTS

A WEEKLY bulletin containing an annotated list of the more important articles appearing in English, French and Italian aeronautical publications is prepared by the library of the Manufacturers Aircraft Association, Inc. This service should be of value to the members who are interested in the subject, as it eliminates any need for consulting the regular periodical indexes which as a rule come out only once a month. Copies of the bulletin will be sent upon request to those interested. Correspondence regarding this service, which is free, should be addressed to the Manufacturers Aircraft Association Library, 501 Fifth Avenue, New York City.

Vol. VII July, 1920 No. 1

A Heavy-Duty High-Speed Engine

By Otis E. Griner[1] and Mark A. Smith[2] (*Members*)

Mid-West Section Paper *Illustrated with* Photographs and Charts

MANY true criticisms have been made in the past few years to the effect that designers have not made sufficient effort to develop engines to meet the conditions of tractor service, but have been forced to use adaptations of automobile engines which were utterly unfitted for this class of work. The same criticisms have been to some degree true of the power units supplied for motor-truck service. The fact that a truly heavy-duty engine for tractor service had never been placed on the market and that development of truck engines had not kept pace with other improvements in truck design was so apparent that shortly after the armistice, the engineering staff of our company, together with prominent consulting engineering talent, commenced the development of an engine which it was hoped would meet the most rigid demands of truck and tractor service. It was desired to produce an engine that would be capable of high speed as well as have the ability to develop the maximum horsepower and torque at low or medium speeds. The results obtained from tests of the engine which was developed have more than justified the deep thought and careful study placed on its design.

The tractor must be

(1) Able to develop great horsepower and torque at tractor operating speeds
(2) Capable of long life when given rough handling and little care. Needs large factors of safety in all parts
(3) Properly lubricated, at all working parts, under all operating conditions
(4) Positively cooled about the valves and cylinder walls while running for hours at a time under full load
(5) Dust-proof

Since the tractor is called upon to operate at full load at low speeds of 2 to 3 m.p.h., it is essential that the engine used develop high horsepower and torque, that it will pull the load at low and medium speeds. The service demanded of the tractor engine most closely approximates that of the stationary engine, and like the latter it should be of a sturdy, rigid construction, simple in design and unlikely to get out of working order easily. The vibrations encountered in tractor service are not like those present in automobile service which might be described as long undulating vibrations. Instead, they are of shorter length and rapid succession. These have a tendency to shake more delicate adjustments out of working order and in a short time. Large factors of safety must be used in the design of all tractor engine parts as the severe shocks they daily receive are sufficient to break parts of light construction.

In the prevailing types of lubrication, the splash, semi-force or full force systems heretofore in use, the lubricant has been supplied with respect to the speed of the engine, and this has invariably meant an over-supply at the idling speed if adjusted to provide the proper lubrication at full loads. Bearing lubrication has been accomplished by injection once in each revolution of the crankshaft and has been almost entirely dependent upon the viscosity of the oil. Impossibility to insure a proper viscosity of the lubricating oil has led to burned-out bearings when the oil film breaks, due to excessive friction occurring when a metal-to-metal contact takes place. The failure of this type of lubrication, often spoken of as grease lubrication, has limited the diameter of crankshafts.

A tractor engine must deliver approximately 75 per cent of its horsepower most of the time, and the other 25 per cent must be available for use when a hard spot is struck, to lift the tractor over stones or obstructions, or for belt work. This is far different than the demands made upon a passenger-car engine. This constant service at nearly maximum capacity demands that the valves and cylinders be much more effectively cooled than those on the passenger-car engine if they are to withstand the great temperatures developed and retained for hours at a time.

The last requirement, that of a dustproof engine, is due to the conditions under which a tractor must work, surrounded by clouds of dust and dirt, and oftentimes neglected by the operator, not receiving the ordinary care and attention given machinery of like nature when used in the shop and factory. One of the places where the dirt enters has been the crankcase breather, and the entrance of even small amounts of dust and grit here ruins the internal wearing parts and causes consequent failure of the engine. The other opening for dirt is through the carbureter, which allows its entrance directly into the combustion chamber. This in brief, we believe, comprises the principal considerations which must be taken care of in the design of a tractor engine.

On the other hand, when considering the demands made on the engine used in truck service, several additional points must be kept in mind. The truck engine must be:

(1) Capable of long life under very severe conditions of service, which requires large factors of safety in all parts
(2) Of sufficient horsepower to take care of an overload of 50 per cent above rated truck capacity
(3) Able to operate at high speeds and under maximum loads in trucks equipped with pneumatic tires

The first of these considerations is nearly identical with similar demands in tractor service. The engine in each class of work is subjected to severe shocks day after day, given little care and must stand up and give a maximum of service in order that the purchaser may realize on his investment.

Truck builders have of necessity installed engines which, when delivering their maximum horsepower, would only handle loads slightly above the rated capacity. The tendency of the user has been to overload 25 to 50 per cent, or put on all the truck body would hold. It is not surprising that truck engines have broken down after comparatively short terms of usage. Again we have the

[1]Service engineer, Midwest Engine Co., Indianapolis.
[2]Sales engineer, Midwest Engine Co., Indianapolis.

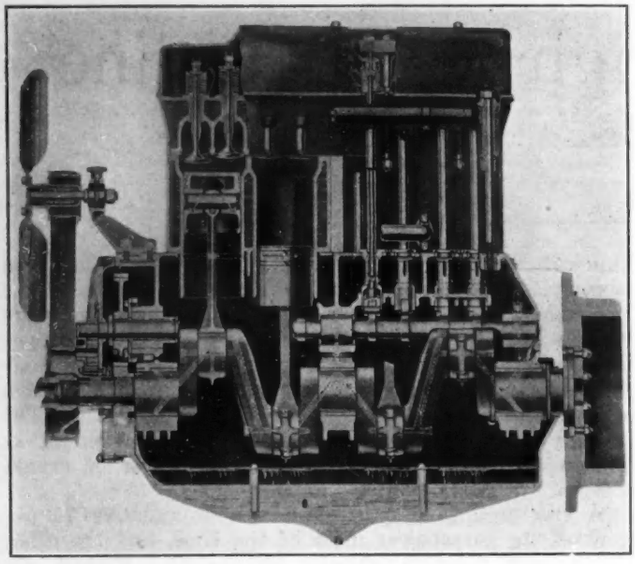


FIG. 1

necessity for more power at low or medium speeds and rugged engine construction to withstand the knocks of hard usage.

With the installation of pneumatic tires on motor trucks has come the demand for greater average speed. The absence of road shock, due to the use of these tires, allows the truck owner to make better average speed, and naturally he desires to avail himself of this profit-gaining factor to the fullest extent. This necessitates the use of engines that can be safely operated at higher speeds than was ever before considered possible.

In summing up the necessary requirements of a universal truck and tractor engine, we consider them to be

(1) Ability to develop high power and torque at low or medium speeds, but also high speeds and maximum load capability
(2) Simple rugged design
(3) A lubrication system insuring the floating of all bearings on a film of oil at all times
(4) Dustproof design

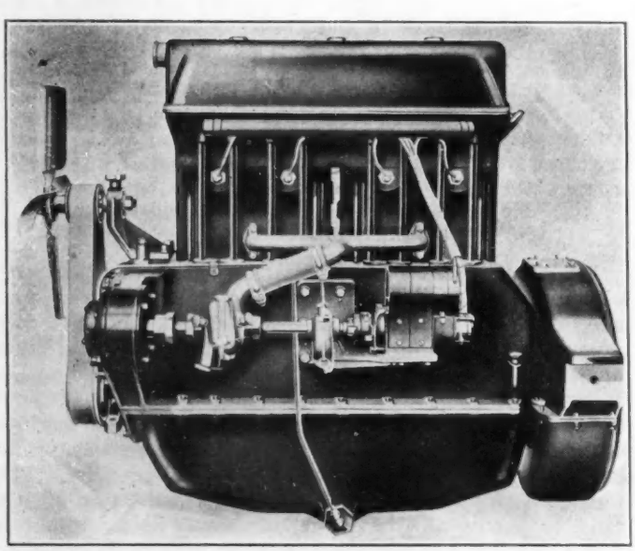


FIG. 2

(5) A superpositive cooling system
(6) Commercial practicability

SPECIAL FEATURES OF DESIGN

The first model developed by us is a four-cylinder four-cycle vertical valve-in-head engine, with a bore of 4½ and stroke of 6 in. (See Fig. 1). All test results given here are from performances with gasoline as a fuel, although this engine is designed for the use of either gasoline or kerosene. The engine is adapted to the use of the heavier fuels.

We have outlined the conditions under which this engine, designed to be used in both the modern tractor and truck, would be compelled to operate, that is, it is called upon to carry as heavy and even heavier loads than those in the older type tractors, and in addition to run at high speeds under full loads for truck usage. This increase in the range of speeds and loads has increased the opportunity for over-lubrication with its resulting troubles, carbon deposits in the combustion chamber and between exhaust valves and seats, fouling of spark-plugs and excessive oil consumption. The general practice in the design of lubrication systems has been to arrange them so that an increase in engine speed automatically increases the amount of lubrication. Our problem is one of arranging for the operation of an engine at

(1) Idling or medium speeds under light loads without excess oiling
(2) Low, medium and high speeds under full load without under-lubrication
(3) Crankshaft and crankpin bearing temperatures below the point where the oil loses its lubricating properties

It is easily perceived that varying the lubrication with respect to engine speed alone is certain to mean under-oiling or over-oiling, as conditions of load and speed change.

By analyzing the phantom views of this engine (See Figs. 2 and 3), it will be seen that the oiling system is of special design and controls the lubricant fed to the bearings with relation to the load on the engine, and not its speed. This is accomplished with an automatically controlled pressure-valve at the forward end of the crankshaft, this crankshaft being completely drilled with a 7/16-in. hole from end to end. A copper tube connects this oil control valve to the intake manifold. Under light-load or idling conditions the vacuum acts more directly on the piston valve, drawing it back against spring compression. The oil then flows freely through the crankshaft under the impulses of the pump and has easy egress from the front end of the shaft. When running under a light load or idling there is therefore no tendency for a large quantity of the lubricant to be forced through the main or connecting-rod bearings and thrown on the cylinder walls.

With the engine under load the throttle-valve is open and the vacuum is lessened, increasing the spring pressure above the piston valve, causing it to close, but with relation to the load on the engine. This pressure on the oil within the crankshaft insures the floating of all bearings on an actual film of oil. The manner in which the oil-leads in the crankshaft are drilled insures the oil being forced into the lower side of all connecting-rod bearings ahead of the bearing pressures. No oil-grooves or shims are used; hence there is no direct lead for the oil to pass out of the connecting-rod bearings, and it must spiral to the outside edge in an unbroken film.

The high peripheral speeds and internal friction de-

veloped when a crankshaft of over 2⅝ in. was used in this size engine has heretofore prevented an increase in crankshaft diameter, since even the force-feed system of lubrication previously used would not properly lubricate at high engine speeds.

The crankshaft used is 3 in. in diameter, having three main bearings. Provision is made for a starting crank on the front end and an integral flange is forged on the rear end to which the flywheel is bolted. Its massive rigid construction absolutely eliminates all stresses on the main bearings and the continuous flow of oil from end to end through the center of the shaft insures a uniform temperature on both crankshaft and crankpin bearings at all times, very nearly the temperature of the oil in the crankcase reservoir (See Fig. 4).

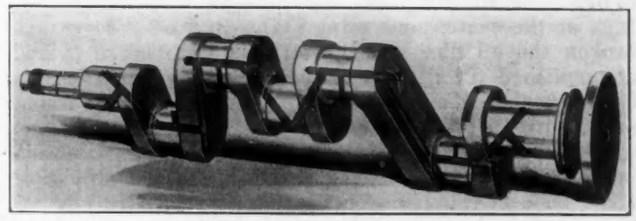


FIG. 4

lubrication at all loads and an excess of oil at idling or low speeds under light load. Therefore, there is no danger to the engine through improper functioning of this system. While this system of oil regulation, proportionate to the load, eliminates over-lubrication, it is necessary to prevent oil being thrown into the cylinders from the centerline bearings. This is accomplished by finishing the crank-throw cheeks nearest these centerline bearings with square corners, which coming in planes outside of the cylinder diameters cause the oil to be thrown outside the cylinder bores and then returned to the reservoir.

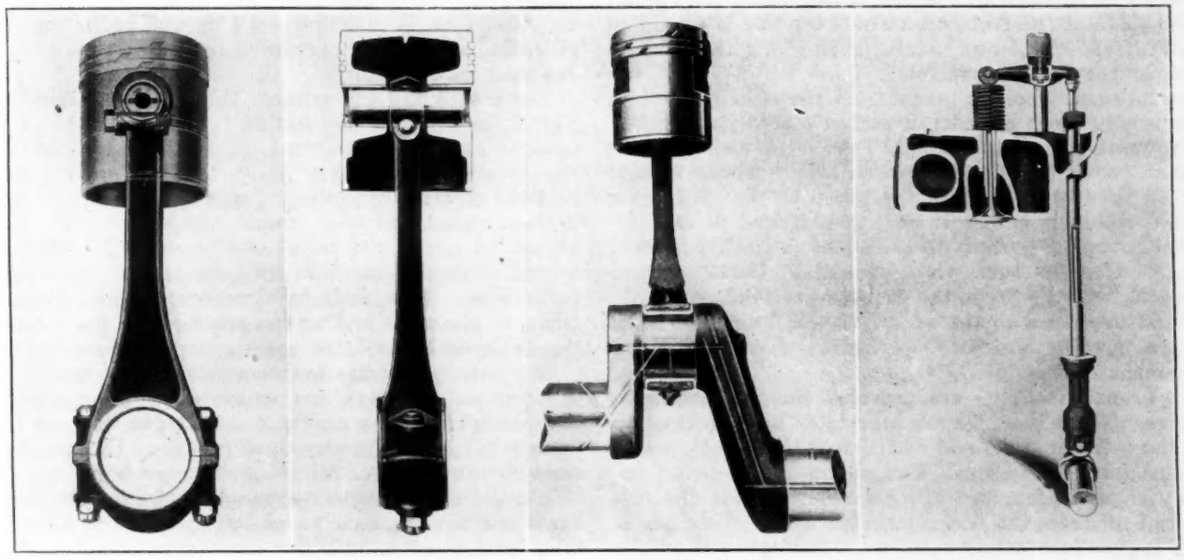


FIG. 5 FIG. 6 FIG. 7 FIG. 8

Regardless of whether pressure is registered on the oil gage in this system, every crankshaft and crankpin bearing is positively oiled and a break in the vacuum control line from the control valve to the intake manifold merely means that the engine bearings will get the maximum

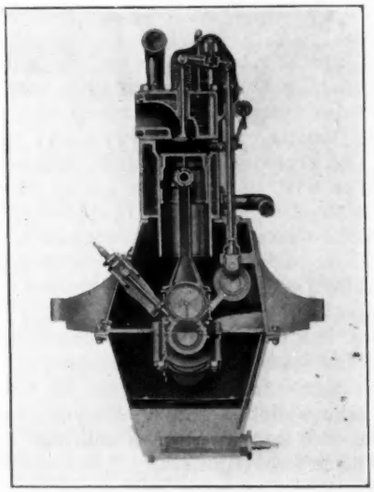


FIG. 3

The connecting-rod which has an I-beam section is made of 0.30 to 0.40 per cent carbon open-hearth steel, heat-treated, accurately machined and carefully tested for alignment and balance. The upper end of the connecting-rod is securely locked on the piston-pin by a heat-treated nickel-steel clamp bolt. This construction gives a maximum of bearing surface for the piston-pin without danger of cylinder scoring through any endwise movement of this pin. The connecting-rods are of special design in that the I-beam section extends around the body of the rod at the crankshaft bearing in such a manner as to take the explosion pressure on the full surface of the crankshaft bearing rather than on one spot at the end of the I-beam section (See Fig. 5). These rods are also reinforced throughout the full length of the bearing so that there is no tendency to wear at the sides in what is commonly known as bell mouthing (See Fig. 6). The tendency of connecting-rod bearings has been to pinch and bind at the split in the bearing, and has usually been met by relieving the bearing metal at this point. On the rod shown sufficient reinforcement has been provided

to overcome this difficulty. The practice of relieving bearings at the center and using shims and oil-grooves has broken the oil film and the oil was lost before it had accomplished the desired results. Every precaution has been taken in this rod design to keep the bearing round and insure an even film of oil. The bearing metal while in a molten state is centrifugally spun into the connecting-rod and cap, eliminating porous spots and providing a 100 per cent bearing. This results in better heat radiation through the connecting-rod (See Fig. 7).

A self-priming geared type of oil-pump is located on the front end of the upper half of the crankcase and driven through a flexible connection from the camshaft. As the inlet and outlet openings are at the top, the oil level in the pump, after the pump has once been primed, can never drop so far that enough oil will not be present to start a circulation in the lubricating system. The oil control valve at the front crankshaft bearing is of piston type, controlled by an adjustable spring and the vacuum action in the intake manifold.

The lubricating oil is taken from the oil-pan through an unusually large cylindrical screen placed horizontally in the lowest part of the sump. Then it passes to the oil-pump on the front of the engine through copper tubing. Another tube leads it from the pump to the rear main bearing, where it enters the crankshaft and flows completely through this shaft to the outlet in the front main bearing. Here its egress is regulated by the oil control valve, and it then flows to the pocket where the gear train runs and overflows to the sump. Leads from the main bearings provide pressure lubrication from the pump and camshaft bearings.

Two bronze bushings are provided for the piston-pin bearings. These bearings are lubricated by oil picked up from the cylinder walls and distributed by spiral grooves over the bearing surfaces. The pistons are relieved opposite the piston-pin, providing a reservoir for the collection of oil from the water-jacketed walls. This cooler oil has higher lubricating value than that taken from the heated interior of the piston. Valve lifters and rollers are lubricated by the throw-off of oil from the crankshaft. The eight tubes enclosing the push-rods balance the pressure in crankcase and valve-cover and provide a fog of lubricant for the overhead valve mechanism. The crankshaft gear revolves in an oil pocket, insuring proper lubrication of the gear train. An overflow from the oil control valve provides a constant oil level in this pocket.

The pistons are of a special gray-iron mixture fitted with three rings ¼ in. wide machined from separate gray-iron castings. The crankshaft design and pressure control prevent excessive lubrication and obviate the necessity for the so-called "scraper" ring.

The main crankshaft bearings are bronze backed and removable, ¼ in. thick with a 3/32-in. babbitt lining. They have a scraped fit in both the crankcase and caps, being securely anchored with four countersunk brass screws. Unusually large bearing surfaces are provided considering the small amount of wear taking place, since the total projected area of the three main crankshaft bearings is 29.82 sq. in. End-thrust is taken care of at the rear main bearing since larger flanges and greater rigidity are obtainable at this point. An 11/16-in. flange on each end of this bearing is provided for that purpose.

Eight steel tubes act as breathers, preventing dust and grit from entering the working mechanism through the crankcase. There is no breathing operation from the outside air.

The circulating water-pump of a floating propulsion type is located on the magneto side of the engine. It has a bronze runner secured on the shaft so it cannot loosen. Water pipes of rigid construction are connected to the pump and radiator with hose of suitable length to eliminate all strains due to radiator connections. Water is admitted at the bottom of each cylinder block, but does not strike the cylinder walls directly. A separate cored passage in the cylinder block leads the water to the cylinder-head where it is forced directly around the exhaust-valve seats. This water, having lowered the exhaust-valve temperature, drops down into large water spaces entirely encircling the cylinder walls. The thermo-syphon action or welling-up of heated water now carries it again to the top of the cylinder block, insuring uniform cylinder wall temperatures. From here it passes out through the water outlet manifold to the radiator.

The combustion chamber is cylindrical in shape with pockets for the valves, machined over the entire surface. Extreme care in machine work as well as in the design of these combustion chambers has been well repaid in low fuel consumption.

The intake and the exhaust valves have a diameter of 2¼ in. in the clear and lift of 7/16 in. The large valve opening and great clearance under the valve head allow the intake and exhaust gases to flow in smooth unbroken streams affording proper scavenging at the highest speeds without undue heating of the exhaust valves. Part of the metal of the valve is removed in a conical depression with its apex at the center of the valve head. This leads to a more equal distribution of metal in the head and allows the heat to pass easily to the valve seat where the cooling water absorbs it.

The push-rod bodies are encased in steel tubes acting as breather openings and supplying a passageway for the oil which is drawn up and into the valve-cover in the form of a spray. This constant passage of oil at uniform temperature through the breather tubes keeps the push-rods at constant temperature and eliminates the troublesome problem of their expansion and contraction. The valve-lifters are of the roller type, with gray-iron guides of close-grained, hard semi-steel mixtures. The push-rod bodies, rollers and roller-pins are made of open-hearth steel, carbonized, hardened and ground all over. Each push-rod assembly can be removed from the outside of the engine without disturbing any of the others. The camshafts have integral cams and are forged from 0.10 to 0.20 per cent open-hearth carbon steel. The wearing surfaces of the cams and bearings are carbonized to a 1/16-in. depth and hardened to scleroscope hardness of from 75 to 95 points. The cams are wide-faced and of large diameter.

A common difficulty with the overhead valve has been the wear occurring in the rocker-arm bearings. This wear necessitates frequent adjustments and has resulted in inaccurate timing, loss of power and noisy engine operation. The rocker-arms used in this engine are of full rocker type with non-slippage action at the point of fulcrum. The wearing surfaces in contact are of large area, that on the rocker-arm being convex, a flat fulcrum on the adjusting screw giving a rolling contact. The rocker-arm is held centered on the adjusting screws at all times, regardless of wear. The adjusting screws are in the rocker-arm bar and can be adjusted while the engine is running. The ends of the rocker-arm and the push-rod have the same full rocker type of contact. The rocker-arms, the ends of the push-rods, the adjusting screw and the ends of valve-stems are hardened.

This engine has two cylinders cast in one block. Eight large-diameter through stanchion-bolts extending through the cylinder-head along the outside of the cylinder into

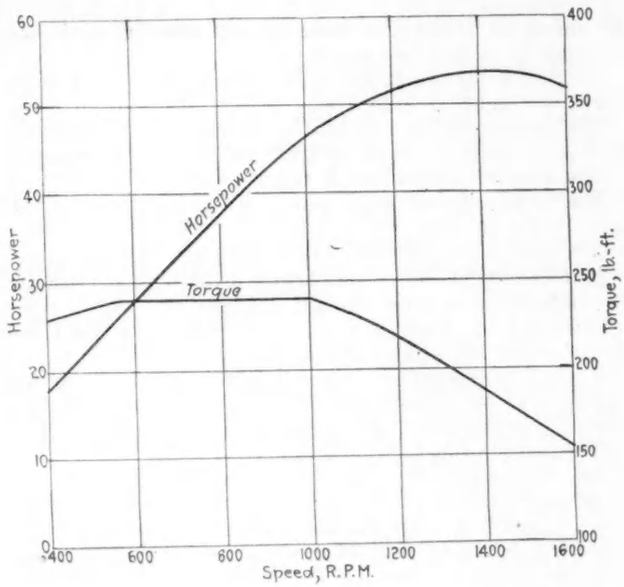


FIG. 9

the crankcase hold the cylinder and the head solidly to the crankcase. This construction eliminates the usual explosion strain on the flanges of the cylinder castings.

Suitable gray-iron castings are used for the crankcase, cylinder blocks, cylinder-heads, pistons and flywheel. Open-hearth or alloy steels are used in parts where great stresses are met and all parts subject to wear are hardened. The crankshaft driving gear and magneto gear are made of 0.30 to 0.40 per cent open-hearth carbon steel, with accurately cut helical teeth. The cam-gear is of gray iron, which meshes into the crankshaft and the magneto gears, giving a contact of gray iron and steel for wear resistance.

The oil-pan and valve-cover are made of pressed steel. The weight of this engine with gray-iron crankcase and No. 3 S. A. E. bell housing, is approximately 1200 lb., including all fixtures for the mounting of standard accessories.

The results of high speed with ability to develop comparatively great power and torque at low or medium speeds are due to the following features of design:

(1) Lubrication by volume under pressure instead of injection once each revolution, or by splash. Not entirely dependent on a certain viscosity of oil for lubrication

(2) Oil pressure and volume regulated with relation to the load, instead of the speed of the engine

(3) Shimless and oil-grooveless bearings

(4) Ample clearance around all bearings and the internal-friction load reduced to minimum. Bearings floated on an oil film at all times, preventing all metal-to-metal contact

(5) Use of a 3-in. crankshaft in 4½ x 6-in. engine. Cooled by large volume of oil circulated through a hollow shaft.

(6) The internal-friction load so slight that engines can be freely turned over by hand when first assembled ready for test run. This means higher power output and thermal efficiency with same amount of fuel consumption

(7) No breather tubes to admit dirt. All vapors from crankcase are used for lubricating rocker-arms and valve-stems

DESCRIPTION OF TEST APPARATUS

A 200-hp. Sprague dynamometer, equipped with scales and metering devices, was used to obtain the horsepower and torque over the entire speed range of this engine. Although capable of high speeds, the engine develops great power and "lugging" capacity at low speeds as is evidenced from the power and torque curves reproduced in Fig. 9. Starting with 15 hp. at 400 r.p.m. the horsepower output increases at an approximate average rate of 10 for every 200 r.p.m. up to a speed of 1000 r.p.m. From here the increase is less directly proportional to the speed, the curve dropping gradually until the "peak" is reached at 1400 r.p.m.

The horsepower developed on the block at 1000 r.p.m. is 46; 54 hp. is developed at 1400 r.p.m. or the "peak." The torque curve is flat at practically all speeds between 500 and 1000 r.p.m.

The timing diagram is shown in Fig. 10.

Due to the restriction of irregularly shaped water passages, no engine of this type is able to show a theoretically perfect curve, which calls for a water-pump output increasing in direct proportion to the engine speed, and would appear as a straight line. The unusually large water passages and the steady performance of the propulsion type pump at all speeds is evidenced by close approximation of the capacity curve in Fig. 11 to the theoretical curve. The capacity of this water-pump at

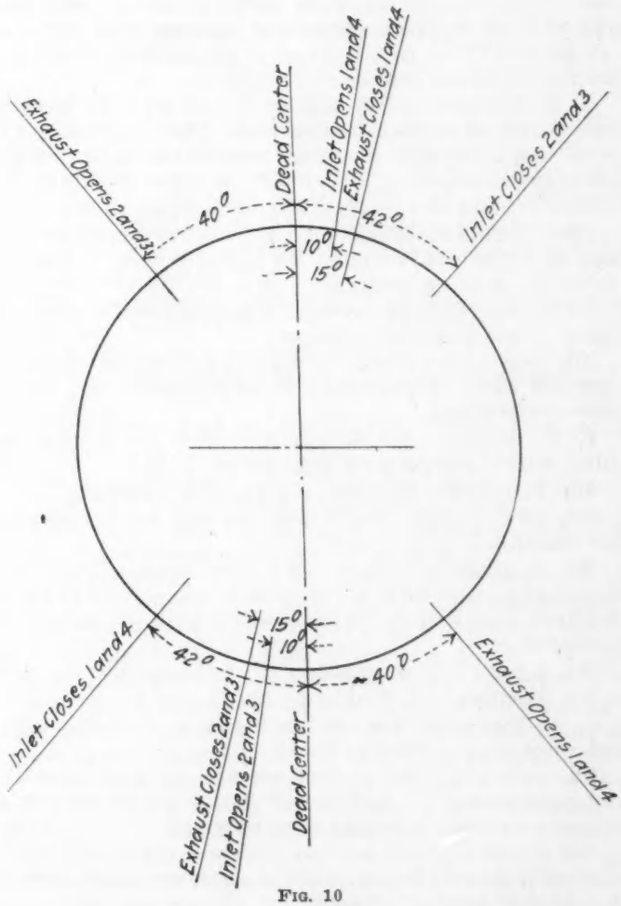


FIG. 10

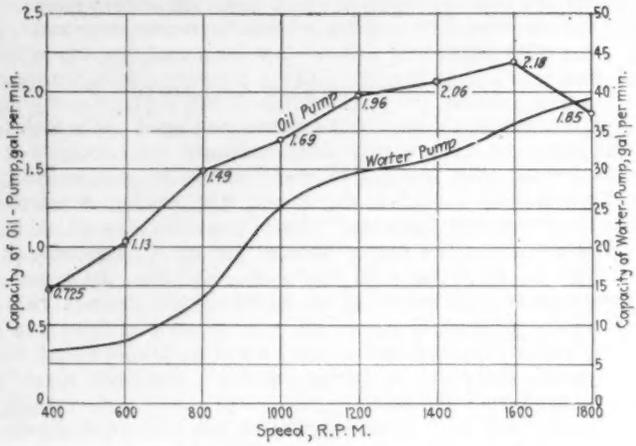


FIG. 11

1000 r.p.m. is 25.1 gal. per min. It rises steadily to 31 gal. per min. at 1400 r.p.m., reaching 38 gal. per min. at 1800 r.p.m.

The geared type of oil-pump has a capacity of 1.7 gal. per min. at 1000 r.p.m., which increases to 2.2 gal. per min. at 1800 r.p.m. This large volume of oil, when forced into main, connecting-rod and camshaft bearings under pressures directly proportional to the load, affords excellent lubrication.

THE DISCUSSION

J. G. ZIMMERMAN:—By having a bore running through the crankshaft and supplying the oil at one end, how does the pressure equalize and insure sufficient lubrication at all points? How do you equalize the amount of lubrication at different bearings?

C. R. SCHULER:—By the even film of oil. We have no oil-grooves or shims in the bearings. By maintaining the even clearance, only a certain amount of oil can escape through the bearings, which equalizes the pressure.

MR. ZIMMERMAN:—That has to be tried out.

MR. SCHULER:—Yes. One or two thousandths will not let much more oil out. We give our shop a limit of 0.003 in. on those bearings.

SECRETARY C. S. RIEMAN:—What is the compression ratio of gasoline and kerosene?

MR. SCHULER:—We carry 90-lb. compression on gasoline and 74 lb. on kerosene; 56 lb. is the ordinary kerosene compression.

R. É. BERG:—How do you overcome the detonating effect with a compression pressure of 74 lb.?

MR. SCHULER:—By getting a dry and a cool gas.

MR. BERG:—Does that depend on the carbureter and the manifold?

MR. SCHULER:—It does. We have some of our own manufacture and we also use some of the standard types. We have good cooling surfaces which keep the wall temperatures down.

MR. BERG:—Do you recollect what the gas velocity is?

MR. SCHULER:—I think it is 180 ft. per sec.

L. W. PIETSCH:—Do you use heavy or light-body oil; and what are the relative films?

MR. SCHULER:—At present we are not restricted to any particular oil. A light oil works very well. We lubricate by volume rather than viscosity. With a light oil we adjust to carry a 35-lb. pressure under full load, which fills the oil chamber and the clearance space around the bearings with a volume of oil. There are no grooves or shims to break the film; it will simply spiral out whether it is light or heavy.

R. W. SMITH:—Are those curves for the volume of oil based on light or heavy-body oil?

MR. SCHULER:—On a Mobile B oil. We have tried Mobile A, lighter grade, and cannot find any difference.

MR. SMITH:—How about the pressures?

MR. SCHULER:—The pressures are maintained regardless of the viscosity.

MR. SMITH:—They are about constant then?

MR. SCHULER:—Yes. A certain amount of oil can get through the clearances around the bearings whether the oil is light or heavy. Many heavy-body oils when hot are of about the same viscosity as some light oils.

F. C. ZIESENHEIM:—On a cold winter morning, as the engine starts up, would there not be considerable air pressure in the crankcase, which would force oil out and make a dirty engine?

MR. SCHULER:—We have not found it so. Pressure is set up in the crankcase, but as the piston goes up and down, there is a little leakage which balances it.

MR. ZIESENHEIM:—It seems that there would be a tendency to breathe. The engine will try its best to breathe at every joint and opening, and it might suck dirt in as well as force oil out.

MR. SCHULER:—It cannot suck dirt in except through the carbureter. It will not suck dirt in by the piston any more than any other engine will. There must be a proper cleaner on the carbureter.

MR. ZIESENHEIM:—Higher pressure in the crankcase will assist the fuel, in passing the piston, to condense and drop into the oil.

MR. SCHULER:—If there is any pressure, it will arise in the crankcase and be relieved. It will go out past the piston, not in. If you do not get the liquid fuel above the piston, you will not get it into the crankcase.

MR. ZIESENHEIM:—If the vapor does go past the piston, it will condense due to the pressure existing in the crankcase, whereas with a lower pressure it would not condense.

MR. SCHULER:—There must be efficient piston-rings to hold the compression, preventing the vapors from passing. With leaky piston-rings, there is bound to be vapor in the crankcase.

MR. ZIESENHEIM:—In some instances engineers have considered putting the crankcase in series with the air washer and carbureter so that the air will first come through the air washer and then through the crankcase into the carbureter and engine. In this way a low pressure would exist in the crankcase and the fuel vapors would be carried out.

MR. SCHULER:—That is a construction that we are not dealing with. Every engineer has his own theory on those details.

L. S. SHELDRICK:—How about the take-up?

MR. SCHULER:—We run on a film of oil and do not get a metal-to-metal contact. Since the bearings do not wear, we do not need to adjust them.

MR. SHELDRICK:—Surely there must be a take-up at some time.

MR. SCHULER:—That has been the theory in connection with all engines heretofore. It is not the theory with this engine. Without any oil-grooves or shims we do not lose the oil through a groove, but we spiral it out after delivering a pencil of oil in the center; we actually run on a film of oil. We have had engines run for a 1000 hr., and when they were taken down they showed that there had been no metal-to-metal contact.

W. O. S. LINCOLN:—I might add a word about the matter of shimless bearings. The latest practice, so far

as I know, in all marine turbines is the same sort of bearing. These turbines have been run for years without shims, by carefully scraping the bearings and using a fairly strong oil pressure on them and running the shafts on a film of oil. There has not been any trouble.

MR. SCHULER:—Several of the best passenger-car builders are adopting shimless bearings.

MR. LINCOLN:—What are the weights of the connecting-rod and the piston? Do you use any special precautions in the preparation of the pistons? Do you heat-treat them in any special way? Have you any difficulty in getting the piston-pin in place and clamping it? Are any special tools necessary?

MR. SCHULER:—The weight of the connecting-rod is about 6½ lb. The piston weighs about 8 lb. The pistons are rough-turned first, then annealed to relieve the strains, and finally finished and ground.

MR. LINCOLN:—At what temperature are they annealed?

MR. SCHULER:—They are brought up to 1100 deg. fahr. and held there in even heat for 30 min. and allowed to cool off with the furnace. We load the pistons into the furnace the last thing after the heat-treatment department is through with its regular work. We warm them up first and then put them in and bring them up to 1100 deg. and let them cool off.

As to getting the piston-pin into place, we have a ¾-in. hole through the side of the piston opposite the clamping screw, through which we can get a screw-driver to tighten the screw. We simply slide the rod up and slip the pin through. There is a screw-driver slot in the end of the pin so that it can be turned until the hole in the rod is opposite the slot through the piston-pin, to get the screws in so they will line up and can be tightened up. We have special equipment all the way through on the pistons. The main thing is to get the piston-pin bore absolutely in line with the outside of the pistons.

SECRETARY RIEMAN:—Do you use any special form of piston-ring?

MR. SCHULER:—We use the standard form.

MR. BERG:—The wrist-pin center is on the center of the cylinder bore, is it not?

MR. SCHULER:—Yes.

MR. BERG:—When the wrist-pin is taken out, can it be put back in end for end?

MR. SCHULER:—It can be put in either way.

MR. BERG:—It has been claimed that the wrist-pin should be put in one way only; that is, after it has been wearing for some time it coordinates with the bore and the rod and the piston and when it is taken out and replaced it should be put back in the same way.

MR. SCHULER:—Unless the pin is damaged or scored it should not make any difference, if the pin is properly hardened and the bushings are in line.

MR. BERG:—In draining the oil from the crankcase, is the oil-pump drained necessarily.

MR. SCHULER:—No. The two outlets on the pump are on the top and it will never drain below the top, so both gears are immersed in oil at all times. On the conventional type of gear pump the outlet and inlet have been on an even line with the meshing point of the two gears. We put both the inlet and the outlet at the top so that the pump is always full of oil.

MR. SHELDRICK:—Does the amount of oil in the pump make it absolutely self-priming?

MR. SCHULER:—Yes.

E. A. DAKER:—How often do you change the oil?

MR. SCHULER:—About once a week, so far.

MR. DAKER:—After a run of how many hours?

MR. SCHULER:—We make no recommendation on changing the oil. We simply tell a man to put in new oil and keep the level up. At present we are not having any trouble with that. The reason for changing the oil is practically contamination, mostly on the kerosene jobs. With a system that does not vaporize the kerosene properly, there is contamination and thinning of the oil. With our system the oil can be thinned down over half with kerosene and still function, because we pump volume through and do not depend on the viscosity to float the bearings.

MR. DAKER:—That is what I could not see about this contamination. You just said the vapor would pass by the piston.

MR. SCHULER:—When there is excess pressure in the crankcase, the air in it is bound to expand. If there is enough pressure it is bound to get out, and the easiest way to get out in this engine is by the piston-rings on suction stroke.

MR. DAKER:—The compression in the combustion chamber would be higher?

MR. SCHULER:—Yes, but the time element of the explosion in the revolution of the engine would not let it by.

F. B. WILLIAMS:—There has been much discussion recently about design and location with reference to spark-plug requirements. At what angle is the spark-plug put in?

MR. SCHULER:—Horizontally at the side.

MR. WILLIAMS:—What is the requisite length?

MR. SCHULER:—That of the ordinary standard plug. We have had no trouble with spark-plugs.

MR. WILLIAMS:—The standard length is, I believe, about 9/16 in.?

MR. SCHULER:—From the flange to the end of the thread 9/16 in. and ¾ or 11/16 in. over the end.

MR. WILLIAMS:—Where do the electrode points come with reference to the edge of the cylinder?

MR. SCHULER:—Outside of it. We have them about ⅛ in. inside the wall, back of the chamber. We have made some experiments in which we put them back 1½ in.; we found we obtained just as much power and they functioned just as well.

MR. ZIMMERMAN:—What angle of spark advance gives the best power?

MR. SCHULER:—About 20 deg.

MR. ZIMMERMAN:—That is smaller than normal, is it not?

MR. SCHULER:—Yes, but with the higher compression we get the same results.

MR. ZIMMERMAN:—That is at 1000 r.p.m.?

MR. SCHULER:—We recommend that speed.

MR. WILLIAMS:—What is the requisite amount of advance as between kerosene and gasoline?

MR. SCHULER:—That depends on the system used and the kerosene mixture. With a dry mixture, the advance is greater. Burning kerosene is a deep problem.

MR. BERG:—Not much stress was put on the hot-spotting and heating of the fuel. I am interested in the detonation. Generally with a compression pressure of 74 lb. kerosene does not mix well. Have you found any special arrangement whereby you eliminated that?

MR. SCHULER:—We have not eliminated that. I think nobody has. We are still doing research work on the subject. We have also adapted our engine to different systems. We carry 74-lb. compression in all our own tests. With some standard makes of manifold we are not carrying the compression that high. Kerosene is a real fuel to burn. I do not think that anybody has really obtained what we call perfect combustion from kerosene.

A Study of Road Impact and Spring and Tire Deflection

By A. F. Masury[1] (*Member*) Metropolitan Section Paper

THE purpose of the tests described herein was to subject various models of truck to shocks far in excess of anything likely to be encountered in actual service, to study the effect of different spring and tire equipment on impact and the effect of unsprung weight upon road impact, as well as the effect of varying speed on these impacts. In other words to study the "grief" on both roadbed and truck chassis and how it is modified by varying factors for unsprung weight, tire equipment and speed. A test[2] along the same line had already been attempted by the Bureau of Public Roads in conjunction with the Bureau of Standards, where road impact was studied by having trucks drop over a low platform upon another platform, where the shock was measured by the compression effected in a copper cylinder. This test was not conclusive, for it took into consideration only one factor, road impact, and left out any study of the stresses set up in the truck, as well as the effect of rebound, etc.; also the distance dropped was very moderate.

To overcome these shortcomings and to study these neglected factors, as well as to prove a large number of empirical and theoretical assumptions on these and kindred subjects we conducted a series of "jumping tests" on Nov. 25, 1919, at Seventy-ninth Street and the North River, New York City, using for the first time a new system of motion pictures to record accurately the results obtained. Trucks were run at speeds of from 15 to 18 m.p.h. along a straightaway course and over a sharp incline. The trucks naturally sprang into the air and struck the ground as from a vertical drop of several feet.

Apparatus Used to Gather Data

In any attempt to study a body in very rapid motion, the observer is hampered by the fact that the human eye is not adapted to follow it beyond a certain speed. In fact, if the movement is sufficiently rapid the object remains invisible. If the speed is relatively less but yet remains considerable, the path of the object may be seen in a general way, and yet only a hazy idea can be obtained as to its performance during the movement. The actions of the springs and tires of a motor vehicle, driven at speed, fall in this latter classification.

In such cases where the naked eye falls down as a recording instrument the use of photographs is generally sought. But the ordinary photograph itself has many limitations. The ordinary motion-picture camera, since it takes sixteen exposures per second, enables a complete record to be obtained with only one camera. Naturally these pictures are only valuable when examined one by one. Were they projected on a screen, the speed would be as great as that of the original object and observation would not be any easier. If they are projected at a speed less than sixteen pictures per second the eye will see instead of a continuous moving picture, a series of separate pictures each slightly different from the preceding one. This is due to the fact that the retina of the eye retains the image projected on it, by the lens of the eye, for 1/16 sec. but no longer. Therefore a series of images coming at a greater rate than sixteen per second will be blended into one continuous "moving picture" but any slower series will remain nothing but a series.

A new type of motion picture apparatus has recently been perfected that will overcome this defect. This apparatus will take pictures on standard film at the extremey high rate of 160 exposures per second, exactly ten times as fast as those produced on the old-fashioned type. Naturally when the film obtained in this manner is projected at the standard rate it will show a moving picture in which the speed of motion is only one-tenth that of the subject, thus giving almost ideal conditions for the accurate and careful study of the subject in question.

In this study of road impact, spring and tire deflection of heavy trucks traveling at speed over conditions simulating bad roads, this system was used. In addition a standard moving picture camera was used. Thus every motion can be projected at the actual speed as recorded by the standard camera taking pictures at sixteen exposures per second and also as taken by the high-speed camera. It is interesting to see what a different conception will be gained of the functions of the various components of the truck chassis when the latter print is seen, and if we remember that until these pictures were made our impressions were the same as those we can gather from the standard part of the film, inasmuch as it reproduces just what our eyes can see, we can realize what this test is actually worth.

A stretch of level ground was used as an approach, and the trucks gathered headway over this for the jumps under their own power. The speed of each truck was determined by taking its time for the last 100 ft. of its run. The take-off platform was built of heavy lumber and consisted of a platform 6 ft. long and raised 1½ ft. at the far end. The horizontal distance which each truck jumped was measured by a curbing along the back of the runway marked off in feet. A large blackboard marked off in 1-ft. squares behind the curbing showed the height of the jumps. As the moving pictures showed the trucks against these devices the position of different portions of the trucks at any instant can be accurately determined. An Eastman kodak-timer showing seconds was placed where it would be photographed on the film. A hand sewing machine with a white card on the plunger was set on a table back of the incline. For each revolution of the crank the plunger rose and fell three times. A man with a stop-watch turned the crank three times per second, thus measuring 1/18 sec. A phonograph motor and turntable were placed on the stone buttress at the near side of the incline. On the turntable was mounted a cylinder marked off in four equal sections. The first was solid black, the second white on top and black on the bottom, the third solid white and the other black at the top

[1] Chief engineer, International Motor Co., New York City.
[2] An account of this test was published in The Journal, April, 1920, p. 265.

and white at the bottom. The governor was set to give a speed of 60 r.p.m., so that the pattern on the cylinder showed ¼ sec.

Trucks Used

Five different trucks were used in this test, consisting of one 2-ton vehicle (E8) having pneumatic tires on the front wheels and solid tires on the rear pair, a 2½-ton truck of the same type (E17) having pneumataic tires on all wheels, a 3-ton truck (E15), a 5-ton truck (E18) and a 5½-ton vehicle (E22), all on solid tires.

To aid the observation the tire rims, one spoke on each wheel and the hub-caps were painted white. A strip of sheet metal marked off in 3-in. bands of black and white extended down past the hub-caps from the lip of the fenders and served to show the rise and fall of the hub. The white rim enabled tire deflections to be measured and the white spoke showed the revolutions of the wheels.

The films were studied both running and still, accurate measurements and calculations being made and conclusions definitely arrived at. By the use of an incandescent projector the films could be stopped at any desired point for special analysis. In doing this work a very small screen was used; the illumination was much brighter, and the picture more distinct. In this way the time in the air of each axle, the time and amount of deflection of each spring and tire, as well as distance moved vertically and horizontally by each of the parts was accurately recorded, both on the original jump and on the rebound.

The Data Obtained and Method of Figuring

The energy exerted by a falling body is equal to the energy required to raise it to the height from which it fell. If the vertical velocity and weight are known, the energy equals the weight times the vertical velocity squared, divided by twice the acceleration due to gravity, or

$$E = \frac{WV}{2g} = \frac{WV}{64.32}, \text{ where}$$

W = Weight in pounds
V = Vertical velocity in feet per second

In the case of a motor truck driven over an upwardly inclined plane the vertical velocity can be obtained from the speed of the truck and the angle of the incline, or

$$V = \frac{S \times 88T}{60} = \frac{22ST}{15}, \text{ where}$$

S = Speed in miles per hour
T = Tangent of the angle of the incline

The average force of a blow is given by the formula

$$F = \frac{E}{D} + W, \text{ where}$$

F = Force of a blow imparted by a moving body
E = Energy of a moving body in foot-pounds
D = Distance in feet required to stop
W = Weight of the body

Combining these three formulas we have

$$F = \frac{W\left(\frac{22ST}{15}\right)^2}{64.32D} + W$$

This formula can be applied to the unsprung weight of a motor truck by taking the deflection in the tires and ground, and to the sprung weight by taking the spring and tire deflection.

The trucks used in the test had weights as follows:

Truck	Weight, lb.					Tires	
	Total	Front	Rear	Unsprung Rear	Sprung Rear	Front Wheels	Rear Wheels
E-8	9,730	3,250	6,480	1,716	4,764	Pneumatic	Solid
E-15	11,870	3,453	8,417	2,140	6,277	Solid	Solid
E-17	10,200	3,100	7,100	1,754	5,346	Pneumatic	Pneumatic
E-18	18,980	5,480	13,500	3,136	10,364	Solid	Solid
E-22	20,500	5,850	14,650	2,446	12,204	Solid	Solid

The different jumps and speeds of these trucks were as follows:

Truck	Speed, m.p.h.			Distance, ft. in.		
	First Jump	Second Jump	Third Jump	First Jump	Second Jump	Third Jump
E-8	16.8	13.6	17.1	14-6	15-0	17-3
E-15	13.6	15.1	9.6	11-1	15-7	7-0
E-17	11.3	16.8	17.1	6-6½	14-7	17-1
E-18	15.1	....	....	9-2	....	....
E-22	13.6	14.3	....	13-5	15-0	....

Applying the combined formula for F to these trucks gives the following results:

Truck	Speed, m.p.h.	V^2, ft.	Tire Deflection, in.	Spring and Tire Deflection, in.	Unsprung Force, ft.-lb.	Sprung Force, ft.-lb.	Sprung Force from Spring Deflection, ft.-lb.
E- 8	17.1	29.4	0.083	0.354	14,336	13,014	3,250
E-15	15.1	30.6	0.083	0.666	13,890	10,757	.....
E-17	17.1	39.4	0.375	0.833	4,624	9,286	2,800
E-18	15.1	30.6	0.083	0.254	21,076	29,004	4,100
E-22	14.3	27.4	0.083	.....	14,866	.....	.....

The deflection per inch of each rear spring as measured and calculated and the deflection of the rear springs and tires in inches as measured from the photographs are given below:

Truck	Spring Deflection, lb. per in.		Spring Deflection, in.	Spring Extension, in.	Tire Deflection in.
	Measured	Calculated			
E-8	1,233	(3,250 in 3¼ in.) 1,000	3¼	4	1
E-15	1,883	(3,700 in 3⅛ in.) 1,183	7	1¼	1
E-17	1,700	(6,400 in 3¾ in.) 2,000	5½	1⅛	4½
E-18	.....	(6,400 in 3⅝ in.) 1,750	2⅛	1⅝	1
E-22	.....	.....	....	....	1

The force of the blow on the ground from the unsprung weight and the sprung weight can be figured by this formula. These forces should not be added together, for they do not occur at the same instant.

Comment and Conclusions

Two of the trucks were of similar design, one (E-8) having solid rear tires and the other (E-17) pneumatic tires on all wheels. A comparison of the results shown by these two is most interesting. The one with solid rear tires weighed 9730 lb., and the one on pneumatic tires 10,200 lb. The lighter one had 6400 lb. on the rear tires and the other 7100 lb. The former had 1000 lb. spring deflection per in. and the latter 1183 lb.

Going over the jump at 17.1 m.p.h., the lighter truck jumped 17 ft. 3 in.; the other, 17 ft. 1 in. Thus they jumped about the same distance at the same speed. Their weight was similar and they had about the same proportion of sprung to unsprung weight. Their springs

were also similar and yet when the forces set up by the shock of landing were calculated an astonishing difference was found, which could be accounted for only by the difference in tire deflection between the solid and pneumatic tires.

The solid-tired truck showed a spring deflection of 3¼ in. and a tire deflection of 1 in. The pneumatic-tired truck showed a 5½-in. spring deflection and 4½-in. tire deflection, all of those figures being taken on the rear wheels only. The force with which the unsprung portions of the solid-tired truck struck the ground was 14,336 lb., as against 4624 lb. with the pneumatic-tired truck. Those on the sprung portions of the solid-tired truck were 13,014 lb., as against 9282 lb. on the pneumatic-tired one.

From this we see that whereas the pneumatic-tired truck had 620 lb. more weight on the rear axle, it went over the same jump at the same speed as the solid-tired one, but owing to the greater deflection of the pneumatic tires, 450 per cent greater than the solids, it hit the ground with only about one-third the impact. In other words, its unsprung impact on the ground was 9712 lb. or 68 per cent less than that of the solid-tired truck. This was not directly due to tire deflection, of course, for we have seen that there was a greater spring deflection, but this is all the more remarkable, for we have seen that these springs were 183 lb. each, or 366 lb. for both rear springs, stiffer than those of the solid-tired truck. The only way it can be accounted for is that the deflection of the pneumatic tires served to lessen the rebound of the unsprung portion of the truck so as to give the effect of a lighter unsprung weight, and consequently to decrease the resistance of the axle to the deflection of the spring. This represents the effect of the impact on the road. The forces acting through the sprung portions of the truck represent the reaction of the blow on the vehicle itself. The sprung force was 3732 lb. or 29 per cent less on the pneumatic-tired truck than on the solid-tired one, which is natural, considering that less impact of the unsprung portions of the road would produce less reactive thrust on the frame.

The conclusions drawn from this test are that the impact of a truck striking the ground after bounding over an obstruction is approximately proportional to the square of the speed and to the weight, and inversely proportional to the resiliency of the springs and tires and the ratio between sprung and unsprung weight. By this is meant that while at a given speed twice the weight will strike the ground with twice the force from a given height, if the same weight strikes the ground at twice the speed, it will strike the ground four times as hard; but that springs or tires twice as resilient will halve it; although with a great unsprung weight the effect of the resilient springs will be lost.

In the test the pneumatic tires saved the road two-thirds of the grief and the vehicle itself one-fourth. Following this thought to a logical conclusion, it would seem obvious that contrary to the popular impression the heaviest trucks might be less destructive to roads than the lighter ones. A 7½-ton truck on pneumatic tires would do less damage to the roadbed than a 5-ton vehicle on solid tires operating at the same speed; moreover, as the heavier truck is a slower vehicle as a rule than the lighter one, still another consideration enters in favor of the heavier truck. And as speed is now shown to have an effect as approximately its square, whereas weight does not, it is seen to be more of a determining factor than weight.

The report of the Bureau of Public Roads shows that the 5½-ton chain-driven truck delivers only 68 per cent of the impact of the smaller capacity worm-driven, standard Class B Army truck. In other words, the smaller truck with a heavy worm axle does greater damage to the road surface than the larger truck with the chain drive and the smaller unsprung weight. Legislators should read this report and note the recommendations of the Bureau of Public Roads, that in restricting the weight and determining the license fees, the unsprung weight should be given consideration before the gross weight.

The Discussion

L. C. Josephs, Jr.:—This subject of impact of vehicles has two aspects which it is always important to keep separate to avoid confusion. One is the impact effects on the vehicle and the other is the impact effects on the pavement. Theoretically action and reaction at the point of impact are equal and opposite, but immediately adjacent to this point the effects may be radically different, as for example, the hammer striking a blow on a hot piece of steel on an anvil. In the tests referred to above, the effects of the impact on the vehicle only are recorded. Mr. Goldbeck's work at the Bureau of Public Roads covers the impact effects on the road only. It is a mistake to try to reconcile the values of these two sets of tests. Any tests of this sort give results largely empirical which cannot be tied up to an exact scientific formula such as $\frac{W V^2}{2 g}$, as there are many indeterminate quantities in the tests such as the friction in the spring leaves and other parts and local accelerations and decelerations of the masses of the various parts, all of which interfere with an exact analysis. Therefore, we can easily reconcile the fact that Mr. Goldbeck finds, for instance, that the impact varies as the 1.7 power of the speed so far as the road is concerned, while these tests show that the impact varies as the square of the speed when measured by the spring and tire deflections. These tests taken in conjunction with Mr. Goldbeck's tests give rise to two lines of thought, improvements in vehicle design and impact effects on the roads.

The cost of building and maintaining highways in this country is increasing rapidly and becoming a large item in the pocket of every taxpayer. Rightly the vehicles using the highways should bear the greatest part of this cost, but lately it has been the tendency to fix license fees so that the motor truck has to bear more than a fair share of this cost, notwithstanding the fact that it is probably of greater economic value to the community than the passenger car. The motor truck looks big and is noisy, and some motor trucks are designed so as to cause terrific injury to roads and therefore, in the popular mind, they cause all the damage to the roads and must be penalized for it. A fairer system of license fees would be one graduated according to the ability of the vehicle to damage the roads. This would place the burden where it belongs and would moreover encourage the design and use of vehicles which would not injure the roads.

Let us examine all the factors entering into the ability of a vehicle to injure the roads as brought out in these various tests. The conclusions are empirical and subject to correction after further tests but are not very incorrect when applied to heavy motor trucks as tested.

(1) Wear-and-tear on the road varies directly as the total weight

(2) Wear-and-tear on the road varies as the percentage of unsprung weight at the rear multiplied by 8.5

(3) Wear-and-tear on the road varies as the 1.7 power of the speed of the vehicle. As speed is a variable quantity, the better way to state this factor is in terms of bore-stroke-number of cylinders, wheel diameter and ratio of direct drive. The 1.7 power is a difficult function for the average man to work out. Employing bore-stroke etc. relations, we will be close enough if we use the square instead of the 1.7 power

(4) For equal loads a larger wheel has a greater contact surface; wear-and-tear therefore varies inversely as the wheel diameter

(5) Pneumatic tires are easier on the road than solid tires. The tests show a difference of 3 to 1. The difference in methods of sizing the two types of tire, however, makes this factor only 2 to 1 when comparing the same size of tire

(6) Wear-and-tear on the road varies inversely with the width of tire

The following is suggested as a formula by which to rate the ability of a vehicle to damage the highways. Vehicles rating over a value of 100 should be ruled off the highways entirely; those rating 100 should pay the maximum license fee; and others rating less should pay less. The actual license would be figured by multiplying this rating by the number of tons total weight.

$$M = \frac{D(1-8.5P) \times (WNBL)^2}{C\,T\,R^2}, \text{ where}$$

M = License rate in dollars per year
D = Diameter of rear wheels in inches
P = Percentage of unsprung weight on rear wheel
W = Total loaded weight of vehicle in tons
N = Number of cylinders
B = Bore in inches
L = Stroke in inches
C = Constant, 1000 for solid tires and 2000 for pneumatic tires
T = Tire width, as marked on tires
R = Ratio of drive on highest speed from engine to wheels

The constants can be made anything according to any base for licensing vehicles, but the formula gives the comparative license fees for different vehicles. On the basis of this new formula given above, for example, a small touring car, say of the Dodge type, would have to pay from $7 to $15 a year. A large touring car of the Cadillac or Packard type would have to pay from $60 to $90 per year. A small 2-ton truck would pay from $25 to $40 per year, a 5-ton truck from $100 to $130 per year and a 7½-ton truck from $125 to $150. In every case the low figure would be paid by the well-designed vehicle and the higher figure by the poorly designed vehicle.

DR. BENJAMIN LIEBOWITZ:—I took the figures which Mr. Masury gave in the paper and worked out the theoretical deflection which would obtain. The main object of this analysis was to find out the effects of the tire, because without the tire, if we had just a system of the sprung weight and the spring had dropped that from any known height, we could calculate, from a simple energy formula, the theoretical deflection; but the presence of the tire and the unsprung weight rather made the whole procedure doubtful. We developed some rather elaborate formulas for it, and we calculated the theoretical curves for E-8, E-17 and E-18, the three trucks for which sufficient data were given from which to make the calculations. The datum that was not given, however, was the static deflection of the tires, from which to calculate the stiffness of this spring; so I guessed at this and took the static deflection of the pneumatic tire as ½ in., and the static deflection of the solid as ⅛ in; that is, I made the pneumatic tire four times as flexible as the solid tire. Those values do not materially change the spring path, because we found in a few experimental trials with the formulas, that a big change in the deflection of the path of the spring did not affect the deflection of the spring, although it did affect the deflection of the tire. In guessing at the static deflection, we had to take a deflection of the tire which was higher than the tire curve, and we have to have fairly complete data for the tire to get it accurately.

A preliminary survey of Mr. Masury's results on the spring deflection shows that they are amazingly small. You will find that the springs will deflect very much more than what he found in theory, if you stop to make a rough calculation. In the case of the solid tire, the tire left the road several times during the impact. In other words, the theory happens to agree with the facts in that case. The pneumatic tire, however, during the first impact, did not leave the road.

We found that if we took the mean position of the tire and calculated the maximum deflection of the spring from that point, we got something which agreed fairly well with the energy formula; that is to say, taking the maximum deflection of the spring in a theoretical case, you could apply the simple energy formula and would get the spring deflection corresponding to the mean position of the tire. This gives the values which we used in the formulas. We had to take all stiffnesses in pounds per foot, instead of pounds per inch, and to take both springs and both tires.

With reference to the spring deflection from the jump test, what Mr. Masury measured I assumed was the deflection from the static deflection. The total travel of the spring in bringing the truck body to rest would be his value, plus the static deflection in each case. By adding these two, I got the total spring deflection; that is, by adding the static spring deflection and the spring deflection from the jump test. From the curve which we plotted, we got the theoretical maximum spring deflection. At one point this was 14.2 as against 5.63, we are comparing results which include static deflection, and at another we got 15 as against 4.94. These are enormous discrepancies between theory and practice.

To get down to some definite basis of comparison, we also determined what we call the average maximum deflection of the tire; that is, the maximum to the mean position of the tire, and it is these values to which the energy formula is applicable. It is also quite likely that what Mr. Masury observed was not the maximum deflection of the spring action but the mean, and what he got, I take it, was the average maximum spring deflection. From the average maximum spring deflection we calculate the sprung force, from the theory, simply by multiplying this by the known stiffness in the spring. In the case of E-8 we got 26,600 ft.-lb.; in E-17 we got 30,800 ft.-lb., and in E-18 we got 53,800 ft.-lb. From these we subtract the body weight and we get a series of values. Then if we divide this by the mass, we get the maximum accelerations. In the case of E-8, in the theoretical case, we would have got a maximum acceleration of 4.6; actually it was 10. If we go through the formulas and get the ratio of stiffness of the springs from theoretical to actual, we find that in the case of E-8 the spring acted as if it were 4.7 times as stiff as it

actually was for the low deflection point. In the case of E-17, the pneumatic-tired vehicle, it was only 2.45 per cent, but in the case of E-18 it was 6.6 per cent.

Mr. Masury gave me the history of these trucks, and I find E-8 was old, E-17 had been driven about 7000 miles, E-18 was old, and E-15 had been driven 1500 miles. The truck which gave the biggest deflection had the newest springs. The total travel, under impact, would have been about 9¼ in., as compared with 7.66 in. under the impact. In other words, it was quite apparent that the new springs behaved much more in accordance with the theory; that is, the newer springs were very much more elastic than the older springs.

Since making these calculations, another source of discrepancy between theory and practice has become apparent, which is that the theory assumes that the load is resting on the floor of the body at the time it struck. It appears that a very considerable portion of the load was not; how much that throws the theory out, I do not know, but in all fairness I must say it makes the whole calculation doubtful as to value.

A. F. MASURY:—I think we will all grant that what Dr. Liebowitz has brought out is perfectly true. We certainly know that the springs which are not new will not conform to our idea of how springs should act.

C. M. MCCREERY:—I think Mr. Masury has shown the tire companies the way in this work. Most of them have been so busy developing the manufacturing processes that they have had no chance to work in this field properly. The high-speed camera certainly gives us a wonderful opportunity to measure and study the deflections, which is probably the most important thing in design, and to compare results in research work. We have made some calculations of deflections of the pneumatic tires and incidentally obtained the same result as Mr. Masury obtained. We have calculated the deflection of the pneumatic tire to be four times that of the solid tire. The thing we want to do, if possible, is to assist Mr. Masury and the Society in getting additional data of a more accurate character.

MR. DAVIS:—I would like to ask if, according to Dr. Liebowitz, the spring deflects more with the solid tire than with the pneumatic?

DR. LIEBOWITZ:—Theoretically the spring deflection is not affected very much by the tire itself. If I remember rightly, the spring deflection would be somewhat less with the pneumatic tire. When we doubled the value of the tire stiffness in one case, we found there was about 0.3-in. difference in the spring deflection.

C. T. MYERS:—On what kind of a road surface were these tests made?

MR. MASURY:—These tests were made on a hard surface of dirt, sand and stone rolled down, which would be commensurate with an average dirt road.

E. R. HEWITT:—I put at least 100 times greater stress on an actual observation of facts in a test than I do on mathematics. If you could get all the preliminary data and have them in correct shape, your mathematical data would no doubt represent the exact effect, but you must realize that the facts are almost impossible to secure in studying a mathematical problem of this character. For instance, you watch this truck jump and the load which is in theory on the truck is in reality off the truck. Therefore, you cannot figure what the sprung weight is.

The moment the truck takes the incline, the tire rebounds and also takes the unsprung weight off the ground. So that any formula is to my mind worthless. The formula for one speed would not correspond to that for another speed. These formulas were taken at a stated speed. However, they would vary with different speeds. In my opinion no formulas of this character are really of any absolute use; they are only a general indication of what would happen.

In the early stages of the motor-truck development I studied the wheel question, and came to the conclusion that the blows were approximately as the square of the speed, and inversely as the size of the wheel. I do not believe you can get any better data than that, and I have not seen any reason to change my opinion.

The unsprung weight is almost impossible to calculate, since the spring above is pushing down the unsprung weight and at the same time there is an elastic body between the unsprung load and the road, whose elasticity is variable with the weight of the tire. The only way I could get at that, with reference to solid tires, was to note the wear on the solid tire per inch of width. I took several trucks and wore the tires out to find out what would take place, and to see if it corresponded with any known formula. In one case I had a weight of 140 lb. per in. of width on the tire, and the truck went 20,000 miles before the tire was worn down. In another case I had a weight of 700 lb. This showed that the wear is somewhat of the order of the cube of the weight per inch of width on the same size of wheel. In the various observations which I have made since, I found that the wear on solid rubber tires is approximately as the cube of the weight per inch of width.

E. FAVARY:—I was very much interested in the examples given us tonight. I believe they are much more important than mere theory. I think Mr. Hewitt was rather mild in his remarks about theory without practice. Very often in using a formula, we neglect many factors which vitally affect the actual result.

Theoretically, in the experiments made by Mr. Masury the spring should deflect much more when the tire is solid; and naturally the greater the impact, the greater should be the deflection of the spring. According to the practical examples which we have seen, the proportionately greatest spring deflection was obtained on pneumatic tires. In the case of two similar trucks with like loads with the pneumatic tires the spring deflection was 5½ in., while with solid tires the deflection was only 3¼ in. Theory does not seem to coincide with practice here and the reason is probably that we do not know exactly what takes place and mere theory does not hold good.

It would seem to me from these experiments that when there is more time for the springs to deflect, they deflect much more, which tends to prove that the time element has something to do with spring deflection. They do not deflect instantaneously according to these experiments, and I would be very much interested if anyone could throw more light upon the subject, but not merely by theory, because we know what theory shows.

DR. LIEBOWITZ:—Mr. Masury's results show that the biggest spring deflection was shown with truck E-15, which had solid tires. The theoretical result showed that the time required for the spring to reach its maximum deflection was 0.15 sec. and that gives ample time for a spring to deflect.

MR. FAVARY:—I was referring to the two similar trucks, equipped with the same springs, the difference being in the tires. We cannot take an example of an entirely different truck, loaded differently and having springs of different length.

A. M. WOLF:—In the table giving the unsprung and

sprung forces which are derived by the last formula, just what is meant by "sprung force"? In the denominator *D*, the distance through which the body acts, the larger this denominator, the less of course will be the resultant force. In other words, the greater the distance through which the body acts, the less the force will be. Now in the table just previous to the one that I referred to, is given the tire deflection. Then there is also listed the tire deflection and the spring deflection, combined. Is it right to consider that the mass, the sprung weight, has acted through that total distance, as computed and made up of the tire deflection and the spring deflection? We know that if the unsprung force is decreased or a similar condition is brought about, the center of gravity of the sprung weight should travel in more of a straight line, considering the normal travel of a vehicle over the road.

We have the solid-tired truck with a spring deflection of 3¼ in. and a tire deflection of 1 in. The pneumatic-tired truck showed a 5½-in. spring deflection and a 4½-in. tire deflection. It seems to me that the two deflections are not occurring at the same time due to a single force; that as we have a rebound from the tire coming up, we have the momentum of the dropping mass coming down, and there is a differential effect there; in other words, we ought to subtract. And, roughly, if we take the 3¼-in. spring deflection and subtract the 1-in. tire deflection, we have 2¼ in. In the pneumatic tire job we have a 5½-in. spring deflection minus a 4½-in. tire deflection, and there the difference is only 1 in. One inch compared to 2¼ seems to bear out the theory that the less the unsprung weight, or the same effect obtained by pneumatic tires, the center of gravity of the sprung mass will run along on more of a straight line.

MR. MASURY:—Mr. Wolf is correct. After I got through giving the deflections, I said that the force of the blow on the ground, from the unsprung weight to sprung weight, can be figured by this formula. These forces should not be added together, for they do not occur at the same time. I think perhaps I said also in a little different form that the spring actually goes through this bow and arrow action when the axle comes to rest, coming down, the spring going through the period action, and the load, even though falling on the body of the truck, does not in any way stop the spring from going through its bow and arrow action.

MR. HEWITT:—There is one further point in the spring matter that is difficult to consider from a mathematical point of view. In this case we have probably a deflection of 6 or 7 in. of the spring, from the unstressed point of the steel. We have also a great weight on that steel. Therefore, we have a 7-in. pendulum which would vibrate at a certain rate with a weight of 3 or 4 tons. The inertia of 3 or 4 tons moving at a given rate is very great, and we cannot affect it by any small blows from above or below which is the reason the spring takes its natural period. After the weight rises, the spring is thrown off and the period of the vibration of the pendulum changes, and when the weight gets on the spring again, the period again changes. Thus we have a very irregular mass to deal with, and a consideration of that from a mathematical point of view is almost impossible.

O. A. MALYCHEVITCH:—I do not know whether any of you have read the report on the exhaustive laboratory experiments on this subject, which was printed in the French magazine *La Technique Automobile* in 1914. As I understood the experiment, it clearly showed that the amplitude of the vibration of the axle depends, all other conditions being equal, upon the unsprung weight only. If we oil the spring and so diminish the friction, we secure a much better result than with an old spring. It is very desirable that these experiments be continued, so that further valuable information can be secured from this research and investigation.

MR. MYERS:—The tests made by the Bureau of Public Roads at Washington are very interesting and worthy of much study. Some of the results indicated are surprising. I am not prepared to accept them as absolute gospel but it is worth while to consider them very carefully. As I remember the figures, when a static load of approximately 7500 lb. to a wheel dropped ¼ in., the blow given the road was equivalent to a static load of over 25,000 lb. When the same wheel load dropped about 3 in., the blow on the road became about 40,000 lb. Here is an indication, of course, of why our roads wave and wear. It seems very likely that the smaller inequalities of the road are just as much a cause of the harm as the truck, and our road builders should heed this.

The subject before us tonight has been attacked in a manner which should lead the way to much real knowledge. We can draw many sound conclusions from these figures, as has been thoroughly brought out by Mr. Hewitt, who is entirely right in the matter. A method has been demonstrated, and we should have more people following it and more working on the theory from the features disclosed.

Our largest problems in the design of motor vehicles are those which involve the absorption of impact loads. The question of shock is the vital one. Anything which will spread shock over an appreciable length of time by spring deflection, tire deflection, or anything else which softens out the impact, will enable the vehicles to stand the loads put on them more satisfactorily.

There are two kinds of vertical loads to which motor vehicles are subjected; one, from those small inequalities in the road surface, which it would seem the pneumatic tire is admirably adapted to absorb; the larger inequalities of the road, it can be shown, are cushioned by the springs which have a greater effective deflection.

We have discovered a most important thing which is that the load parts company with the body; and in more than one case it was brought out that on the rebound the body came up and met the load, which certainly took much of the shock load off the chassis and the tires.

Another point has been brought up, as pointed to by Dr. Liebowitz; that is, as trucks grow older, the springs become harsher and harder. I know of Dr. Liebowitz' theory that the steel ages and in itself becomes more resistant to flexure. The point seems to be well taken and is worthy of more consideration than it usually gets. Our springs, when new, contain a certain amount of graphite lubricant, but that works out in a few months and they become stiffer to the detriment of the chassis and the load. The continuous lubrication of vehicle springs has been very successfully demonstrated.

I believe that trucks will be operated with greater loads and at higher speeds. An example of what can be done was demonstrated recently in California by a 3½-ton truck, loaded about normally. The builder of the vehicle had been urged to equip his product with pneumatic tires. He was very willing to be shown the advantage of pneumatic tires, and this truck was so equipped. It was run from San Francisco to Los Angeles and return, down the coast and up the valley, a distance of 890 miles in the round-trip. The drivers were men who had had much experience in driving trucks equipped with pneu-

matic tires, and they were told not to spare the truck but to go down and make the trip as fast as they could. The speed for that trip averaged 24.75 m.p.h. and went as high as 40 m.p.h. The truck came through without any mechanical trouble at all.

The truck was then equipped with solid tires, and the gear reduction was changed so that the tractive factor was approximately the same as with the pneumatic-tire equipment. Again the truck went over the same 890-mile course but the average speed was about 2 m.p.h. faster with the solid tires than with the pneumatic tires, or 26.90 m.p.h. Still the truck came through without any mechanical trouble, except that an engine piston burned out just before the second trip was started. On the second trip, 200 miles out of San Francisco, the truck got down to a stream bottom and one of the rear tires was badly slivered before the truck got out on the road again. Piece by piece that tire parted from the rim, until, within 200 miles of San Francisco, on the return trip up the valley, there was just one piece of solid tire about 6 in. long on the rim. This pounded against the road like a trip hammer and the driver had to cut the speed from 45 m.p.h. to about 25.

The roads are good in California, and I think that a large part of that performance was due to this. The difference between the pneumatic and the solid tire was almost entirely due, so far as the speed was concerned, to the difference in the gear reduction, which favored the solid tire by about 10 per cent, showing that it was the engine speed which was the critical factor and not the speed at which the tire would run. The gasoline consumption for the solid tire also excelled that of the pneumatic tire, showing again that the tractive factor was the controlling feature there. A seven-speed transmission was used, giving the truck the ability to run at a very high road speed in respect to engine speed, while at the same time affording a low-gear reduction that enabled the truck to climb a 25 per cent grade.

This all goes to show that remarkable things can be done with these trucks if the well recognized detail features of construction are carried out. The main thing, however, is the absorption of the shocks of the road.

A TRACTOR ENGINE TEST

(*Concluded from page* 85)

nearly constant as possible in the tests; at about 200 deg. fahr. at the point of leaving, the rise being about 70 deg. fahr.

Regarding the influence of two spark-plugs, some illuminating tests have recently been carried out by the Bureau of Standards. The velocity of flame propagation was measured in a 5 by 7-in. Liberty engine while the engine was actually running. From some computations I have made it appears that, even at 1800 r.p.m., the velocity of flame propagation with a single spark-plug was enough to spread the combustion through the charge before the end of the working stroke. It was not enough, however, to ignite the charge completely and burn it in the clearance space at a reasonably constant volume, say in one-eighth of the stroke. Since greater efficiency is obtainable by combustion in the clearance space than by combustion during the whole stroke, the efficiency of a 5 by 7-in. engine at 1800 r.p.m. can be improved by two spark-plugs. That of a smaller engine, or a 5 by 7-in. engine at a lower speed, cannot be improved in the same ratio.

The type of fuel used is specified in great detail in the paper. It was a standard gasoline and the constancy of quality was checked repeatedly by distillation tests. The test here reported is only the first half of a test. It is proposed to run the same engine on kerosene and compare its performance when burning that kind of fuel with that obtained from gasoline.

In concluding, I wish to say that there is an omission in the paper. The tests reported were of an extremely wearying character and lasted over six months. They were possible only by the extreme interest of the men. I feel it my duty to thank publicly Messrs. McCune, Neumann, Dato and Casey for the work they did.

CALIBRATION OF BAROGRAPHS USED BY MAJOR SCHROEDER

THE two 34,000-ft. barographs used by Major Schroeder in his altitude flight last February were investigated by the Bureau of Standards not only for the purpose of determining the atmospheric pressure reached at the ceiling of Major Schroeder's flight, but also to determine the change in their calibration with temperature. The results were compared with those obtained from tests conducted last September and the instruments were found to repeat within the experimental error. An interesting part of the investigation consisted in giving the instrument two flight-history tests. These tests are based on the assumption that a well-seasoned instrument will always give the same indications when subjected to identical conditions. The test consists in putting the instruments in a chamber where the air pressure and temperature can be varied in exactly the same way as they varied during the flight; or, in other words, the pens of the instruments are made to follow the trace on the charts recorded during the flight. As the temperatures experienced by an airplane at great altitudes are lower than those which can be obtained by an ordinary refrigerating system, it is necessary to use carbon dioxide apparatus to produce the lower temperature within the chamber. The temperature test of these instruments is very important because from them temperature-pressure correction curves can be computed and if it is found that the temperatures observed by the pilot during the flight are in error, these curves provide a means of correcting them. They can also be used to compute the most probable altitudes of any future flight, if it is not possible to carry out a new flight-history test.—Air Service News Letter.

The Heat-Treatment of a High-Chromium Steel

By H. J. FRENCH[1] (*Member*) AND YOSHITO YAMAUCHI[2] (*Non-Member*) *Illustrated with* PHOTOGRAPHS AND CHARTS

HIGH-CHROMIUM steel containing about 11 to 15 per cent of chromium and usually 0.20 to 0.40 per cent of carbon is manufactured under the name of stainless steel, because of its peculiar property when properly hardened and finished of resisting oxidation and corrosion by the ordinary agents. Originally employed in the manufacture of cutlery, such steel has proved its value in other fields and gives promise of wider application. It has been successfully used to replace high-nickel and high-speed steels for valves in airplane and automobile engines and will probably receive attention for other machine parts subjected to corrosive action or oxidizing service conditions.

One of its main disadvantages is its high-chromium content which makes it a costly alloy. It is also quite sensitive to mechanical and thermal treatments, but combines high strength and good ductility with its ability to resist corrosion which is a combination difficult to duplicate. While chromium was one of the first of the steel-alloying elements, its use was for many years confined to high-carbon products due to the difficulty of manufacturing carbon free chromium. So-called stainless steel is, therefore, one of the indirect results of improvements in the manufacture of carbon-free ferroalloys.

Comparatively little information has been published concerning the physical properties of stainless steel. In 1917, W. H. Hatfield[3] published results of tensile and impact tests of a steel containing 0.30 per cent of carbon and 13.0 per cent of chromium. A comparison between air, oil and water-quenching followed by relatively high temperature tempering is given. His tensile-test results have also been incorporated in the tentative report[4] of the Iron and Steel Division of the Society and constitute the major portion of the physical test data there given. The latter report, however, includes a valuable and interesting discussion of the proper methods of working, annealing and finishing of such steel and a comparison between stainless, high-speed and some commonly used structural alloy steels in resistance to oxidation at high temperatures.

A rather complete discussion of the properties of stainless steel is given by Seidell and Horvitz in *The Iron Age*.[5] The work of previous investigators on high-chromium steels of varying carbon contents is reviewed, and typical differential heating and cooling curves are given for a steel containing 0.33 per cent of carbon and 11.02 per cent of chromium. The authors clearly show the suppression of the ferrite transformation together with the lowering of the A_1 transformation as maximum heating temperature is increased. Brinell hardness values under varying quenching and tempering treatments and relation to so-called red-hardness are also shown. Few data are given, however, on the tensile properties.

MATERIAL AND METHODS USED

To determine the effect of various heat-treatments on the tensile properties of such high-chromium steel and to throw further light on its possible use for various machine parts, a series of tests has been carried out on two bars of annealed 1-in. hot-rolled rounds of the following composition:

Elements	Composition, per cent Ladle	Check
Carbon	0.270	0.240–0.290
Manganese	0.520	0.360–0.380
Phosphorus	0.011	0.009
Sulphur	0.009	0.014
Silicon	0.695	0.700
Chromium	12.400	13.200

In the annealed condition, as supplied, the steel showed the following tensile properties, in which condition it machines quite readily:

Proportional Limit, lb. per sq. in.	64,000
Tensile Strength, lb. per sq. in.	106,900
Elongation in 2 in., per cent	26.0
Reduction in Area, per cent	58.5
Brinell Hardness Number	222
Shore Hardness Number	34

All treatments were carried out on Zimmerschied tensile test-specimens, the gage length being left 1/32 in. larger than the specified diameter, 0.505 in., for grinding after heat-treatment. The effective diameter in treatment was, therefore, 17/32 in. For hardening, samples were heated in gas-fired furnaces, while for tempering, an oil bath was used at 400 deg. fahr. (205 deg. cent.); a two-to-one mixture of sodium and potassium nitrates, at 800 and 1000 deg. fahr. (427 and 538 deg. cent.) and a Hoskin's electric muffle furnace, at 1200 deg. fahr. (649 deg. cent.). All temperatures up to and including 2100 deg. fahr. (1149 deg. cent.) were measured by standardized 14-gage chromel-alumel couples connected to a Leeds & Northrup potentiometer. Quenching from 2250 deg. fahr. (1233 deg. cent.) was controlled by a Leeds & Northrup optical pyrometer.

All tensile tests were made on a 100,000-lb. Riehle testing machine. Proportional limits were obtained from stress-strain diagrams, the deformation being taken with an extensometer reading to 0.0002 in. Brinell hardness values were obtained under standard conditions, 3000-kg. load on a 10-mm. ball ± 0.025 mm., using an Alpha machine, and a recording scleroscope was used for Shore hardness.

Before carrying out the various thermal treatments heating and cooling curves were taken with the modified Rosenhain type furnace in use at the Bureau of Stand-

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[3]Heat Treatment of Aircraft Steels, by W. H. Hatfield, *Automobile Engineer*, vol. 7, p. 209.
[4]JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS, vol. 5, pp. 262 and 263.
[5]Physical Qualities of High-Chrome Steel, by L. R. Seidell and G. J. Horvitz, *The Iron Age*, vol. 103, pp. 291-294.

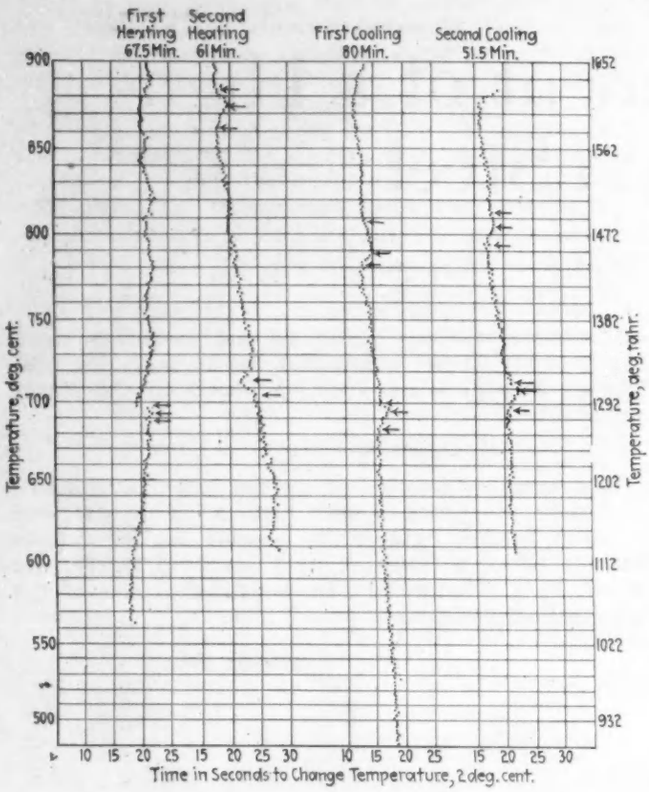

First Heating 67.5 Min.
Second Heating 61 Min.
First Cooling 80 Min.
Second Cooling 51.5 Min.
Temperature, deg. cent.
Temperature, deg. fahr.
Time in Seconds to Change Temperature, 2 deg. cent.

FIG. 1—THERMAL ANALYSIS OF A HIGH-CHROMIUM STEEL

ards, a description of which will be found in the August 1919 *Bulletin of the American Institute of Mining and Metallurgical Engineers.*[6] The inverse-rate curves obtained are shown in Fig. 1.

VARYING QUENCHING AND TEMPERING TEMPERATURES

The effects of varying the oil-quenching temperature on the tensile properties and hardness are shown in Fig. 2, based on results given in Table 1. For the temperatures chosen interesting features are noted:

(1) The best combination of strength and ductility is obtained in quenching from 1750 deg. fahr. (953 deg. cent.) which condition is coincident with the maximum tensile strength

(2) Maximum hardness and maximum strength do not coincide

(3) Ductility, as measured by both the elongation and the reduction in area, decreases rapidly as the quenching temperature is increased. It reaches a very low value at 1850 deg. fahr. (1010 deg. cent.), above which temperature it remains practically constant. This decrease in ductility and also the increase in grain size with an increase in the oil-quenching temperature is clearly indicated in the fractures obtained in the tensile tests, as shown in Fig. 3

(4) Minimum ductility, as measured by both the elongation and the reduction in area, does not correspond to the maximum tensile strength or the proportional limit

(5) The proportional limit is a difficult factor to determine in cases where the ductility is low, its exact value depending largely upon the observer. Fig. 4 is a typical stress-strain diagram and shows the marked resemblance to a curved line

The effect of varying the tempering temperature up to about 1200 deg. fahr. (649 deg. cent.) on samples previously quenched from 1750 deg. fahr. (953 deg.

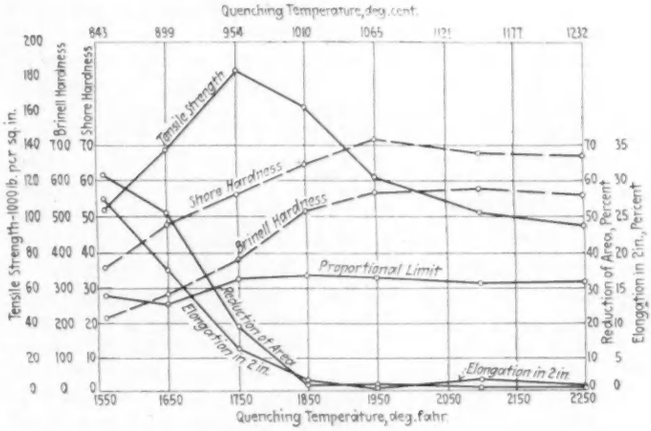


FIG. 2—EFFECT OF VARYING OIL-QUENCHING TEMPERATURE ON THE PHYSICAL PROPERTIES OF A HIGH-CHROMIUM STEEL

cent.) and 2100 deg. fahr. (1149 deg. cent.) is shown in Figs. 5 and 6. The actual test results are given in Table 2, while the fractures are shown in Fig. 7. It is interesting to note that the strength of this steel is not lowered upon tempering for short periods of time until a temperature in the neighborhood of 800 deg. fahr. (427

[6]Use of a Modified Rosenhain Furnace for Thermal Analysis, by H. Scott and J. R. Freeman, Jr. *Bulletin of the American Institute of Mining and Metallurgical Engineers*, No. 152, pp. 1429-1435.

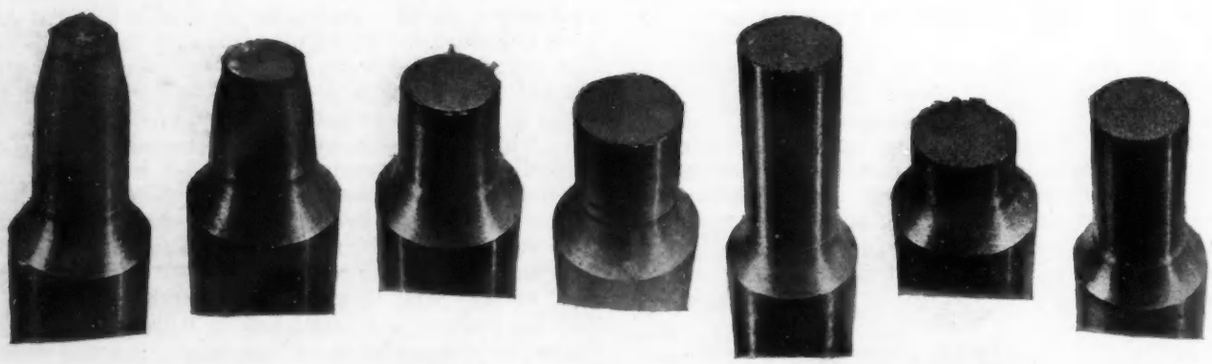


FIG. 3—FRACTURES OF QUENCHED HIGH-CHROMIUM STEEL

The Specimens Which Are Approximately Full Size Were Quenched in Oil from the Temperature in Degrees Fahrenheit Indicated Under Each Fracture

TABLE 1.—EFFECT OF VARYING THE OIL-QUENCHING TEMPERATURE ON THE PHYSICAL PROPERTIES OF A HIGH-CHROMIUM STEEL

Test Number	Oil-quenched from		Tensile Strength, lb. per sq. in.	Proportional Limit, lb. per sq. in.	Elastic Ratio, per cent	Elongation in 2 in., per cent	Reduction in Area, per cent	Brinell Hardness Number	Shore Scleroscope Hardness
	Deg. Fahr.	Deg. Cent.							
A 1	1562	850	103,150	55,500	53.8	28.5	61.0	217	35.5
B 1			103,900	56,000	53.9	26.0	61.5	218	
Average			103,525	55,750	53.8	27.3	61.3	218	35.5
A 2	1652	900	133,000	50,000	37.6	17.0	52.0	278	47.6
B 2			140,800	50,500	35.9	17.5	49.0	289	
Average			136,900	50,250	36.7	17.3	50.5	283	47.6
A 3	1750	955	178,800	69,000	38.6	6.0	19.5	383	55.6
B			188,050	60,000	31.9	6.5	18.5	373	
Average			183,425	64,500	35.2	6.3	19.0	378	55.6
A 4	1850	1010	152,650	67,500	44.2	1.5	0.5	507	64.2
B 4			170,500	65,000	38.1	1.5	2.0	510	
Average			161,575	66,250	42.1	1.5	1.3	509	64.2
A 5	1950	1065	128,850	69,000	53.6	1.0	2.0	555	71.3
B 5			112,700	61,500	54.6	0.0	0.5	569	
Average			120,775	65,250	54.1	0.5	1.3	562	71.3
A 6	2100	1149	98,400	67,000	68.1	1.0	1.0	567	67.4
B 6			104,100	57,000	54.8	2.0	1.0	582	
Average			101,250	62,000	61.4	1.5	1.0	574	67.4
*A 7	2250	1232	96,500	63,000	65.3	0.5	0.5	569	
B 7			91,800			0.5	0.5	548	66.9
Average			94,150	63,000	65.3	0.5	0.5	559	66.9

*Broke outside of punch-marks.

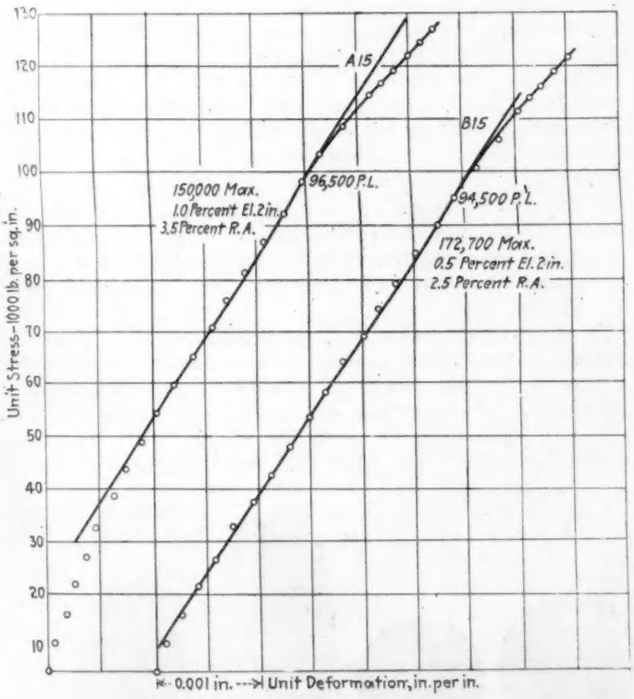


FIG. 4—STRESS-STRAIN DIAGRAMS OF QUENCHED AND TEMPERED HIGH-CHROMIUM STEEL

deg. cent.) is reached. Between 800 deg. fahr. (427 deg. cent.) and 1000 deg. fahr. (538 deg. cent.) a marked decrease in strength and an increase in ductility is obtained.

The inherent brittleness of those samples quenched from the higher temperatures probably accounts for the marked increase in the tensile strength with an increase in the tempering temperature up to 800 deg. fahr. (427 deg. cent.) on those samples quenched from 2100 deg. fahr. (1149 deg. cent.) as shown in Fig. 6. Short-time tempering gradually relieves the initial stresses set up

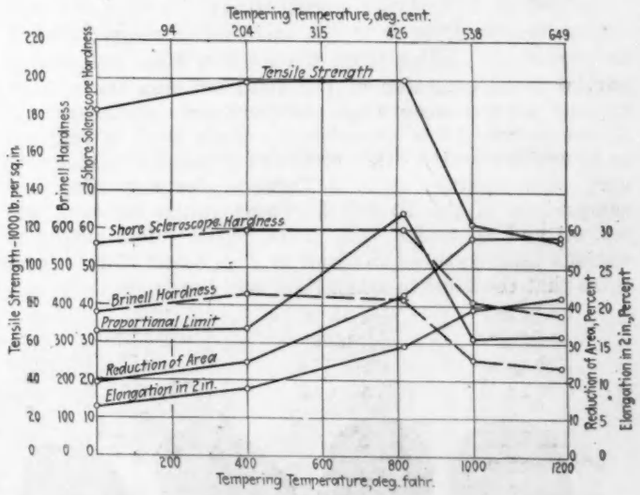


FIG. 5—EFFECT OF VARYING TEMPERATURES ON THE PHYSICAL PROPERTIES OF A HIGH-CHROMIUM STEEL, OIL-QUENCHED FROM 1750 DEG. FAHR.

in quenching until at about 800 deg. fahr. (427 deg. cent.) these are overcome to such an extent as to allow the material to develop its maximum resistance to static tensile stress. Evidence of brittleness, but to a smaller degree in those samples quenched from 1750 deg. fahr.

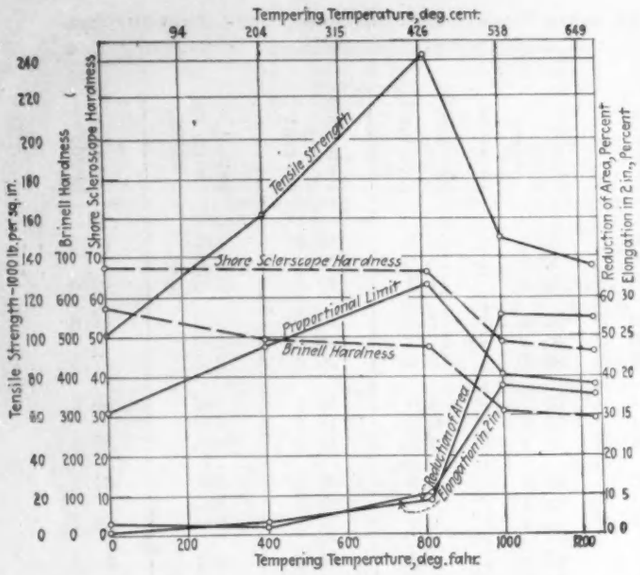


FIG. 6—EFFECT OF VARYING TEMPERATURES ON THE PHYSICAL PROPERTIES OF A HIGH-CHROMIUM STEEL, OIL-QUENCHED FROM 2100 DEG. FAHR.

(953 deg. cent.), is likewise clearly shown by the shape of the tensile-strength curve in the range of low-tempering temperatures, Fig. 5.

It is possible that the low tensile strength of these hard specimens is affected somewhat by the conditions of heating. If the specimens are not perfectly straight, the stress applied in the testing machine is not parallel to the axis of the specimen and as the material has low ductility it cannot adjust itself and so breaks at a value lower than the true tensile strength. However, as all test-specimens were ground after heat-treatment, this effect has been kept at a minimum.

CONSTITUTION

According to Guillet's constitutional diagram the steel under consideration is in the martensitic range; that is, on normal air cooling from above the critical ranges only partial transformation of the solid solution takes place so that on reaching room temperature martensite remains as the stable constituent. Such steel is referred to as self-hardening steel, and it is necessary to resort to very slow cooling, as in a furnace, for annealing. A comparison of the Brinell hardness values between water, oil and air-cooled 1-in. disks, ¼ in. thick, heated to various temperatures is given in Fig. 8 and clearly indicates that the steel in small sizes will harden equally well in air, oil or water. In practice furnace cooling from about 1400 deg. fahr. (760 deg. cent.) to a temperature in the neighborhood of 1000 deg. fahr. (538 deg. cent.) followed by air-cooling to room temperature is a satisfactory method of annealing. By heating to about 1750 deg. fahr. (953 deg. cent.) and cooling in a manner similar to the above the steel is brought into an even softer condition though one not quite as satisfactory for ordinary machining.

In this connection it is interesting to note comparative tensile values obtained by Hatfield[5] on samples of stainless steel containing 0.30 per cent of carbon and 13.0 per cent of chromium cooled in air, oil and water and subjected to high-temperature tempering between about 1000 deg. fahr. (538 per cent.) and 1400 deg. fahr. (760 deg. cent.). His results are produced in part in Table 3.

Micro-examination of all heat-treated tensile-test samples was made, and in some cases reveals interesting structures. For etching the reagent mentioned by Seidell and Horvitz[6] consisting of a mixture of two parts of a 50-per cent solution of hydrochloric acid, two parts of 15-per cent solution of ammonium persulphate and one part of concentrated alcoholic solution of nitrophenol was at first used. This, in general, gave satisfactory results but a mixture of two parts of concentrated nitric acid and one part of concentrated hydrochloric acid diluted with three parts of water was finally adopted as meeting all requirements. With this reagent a satisfactory development of the structure was obtained by immersion for from 30 to 90 sec. Samples quenched from the highest temperatures without subsequent tempering required the longest immersion, while the remainder required only 30 to 60 sec.

All samples oil-quenched from above 1750 deg. fahr. (955 deg. cent.) without subsequent tempering show a martensitic structure as shown in Fig. 9. Above 1850 deg. fahr. (1010 deg. cent.) the "needles" become markedly large, and in those samples quenched from 2100 and 2250 deg. fahr. (1149 and 1233 deg. cent.) there is evidence of a retention of the solid solution. A portion of the cross-section of sample *A*6, in particular, exhibits the polygonal structure characteristic of austenite. A partial preservation of these grain boundaries is evident also in sample *A*7 quenched from 2250 deg. fahr. (1233 deg. cent.).

A close examination of these micrographs further reveals minute carbide globues in samples *A*1, *A*2 and *A*3 representing the steel as oil-quenched from temperatures between 1562 and 1750 deg. fahr. (852 and 955 deg. cent.). The steel as quenched from 1750 deg. fahr. (955 deg. cent.) and 2100 deg. fahr. (1149 deg. cent.)

F 11	B 12	B 13	B 14	B 15	B 16	B 17	B 18
1750	1750	1750	1750	2100	2100	2100	2100
400	815	1000	1235	400	815	1000	1235

FIG. 7—FRACTURES OF QUENCHED AND TEMPERED HIGH-CHROMIUM STEEL

The Upper Figure under Each Specimen Represents the Temperature in Degrees Fahrenheit at Which It Was Quenched in Oil and the Lower Is the Temperature at Which It Was Tempered for 30 Min. The Fractures Are Magnified Approximately 1.6 Times.

TABLE 2.—EFFECT OF VARYING TEMPERATURES ON THE PHYSICAL PROPERTIES OF A HIGH-CHROMIUM STEEL, OIL-QUENCHED FROM 1750 AND 2100 DEG. FAHR. RESPECTIVELY.

Test Number	Oil-Quenching Temperature		Tempering Temperature		Tensile Strength, lb. per sq. in.	Proportional Limit, lb. per sq. in.	Elastic Ratio, per cent	Elongation in 2 in., per cent	Reduction in Area, per cent	Brinell Hardness Number	Shore Scleroscope Hardness
	Deg. Fahr.	Deg. Cent.	Deg. Fahr.	Deg. Cent.							
A 11			400	204	195,900	66,500	34.0	9.5	30.5	430	60.7
B 11					200,500	68,000	33.9	8.0	18.5	425	58.5
Average					**198,200**	**67,250**	**34.0**	**8.8**	**24.5**	**428**	**59.6**
A 12			815	435	219,700			15.5	46.3	433	61.0
B 12					190,350			13.0	42.7	400	60.2
A 19					188,450	128,000	67.9	16.0	38.5	420	58.7
Average	1750	955			199,500	128,000	67.9	14.8	42.5	418	60.0
A 13			1000	538	121,650	61,000	50.2	18.5	57.2	256	41.8
B 13					122,350	63,500	51.9	20.5	57.8	252	39.8
Average					122,000	62,250	51.0	19.5	57.5	254	40.8
A 14			1235	668	112,200	63,000	56.2	22.5	58.0	233	37.7
B 14					115,400	64,000	55.5	19.5	57.8	238	37.4
Average					113,800	63,500	55.8	21.0	57.9	236	37.6
A 15			400	204	150,100	96,500	64.3	1.0	3.5	502	66.8
*B 15					172,700	94,500	54.7	0.5	2.5	492	66.7
Average					161,400	95,500	59.5	0.8	3.0	497	66.8
†A 16			815	435	243,300	128,000	52.6	8.0	14.0	474	66.3
†B 16					242,400	125,000	51.6	2.5	2.5	477	66.2
Average	2100	1149			242,850	126,500	52.1	5.3	8.3	476	66.3
A 17			1000	538	149,100	80,500	54.0	18.5	55.5	310	48.6
B 17					151,250	81,500	53.9	19.5	55.0	317	48.9
Average					150,175	81,000	54.0	19.0	55.3	314	48.8
A 18			1235	668	135,450	75,000	55.4	17.5	54.0	286	46.4
B 18					136,950	78,000	56.9	18.0	55.0	297	46.4
Average					136,200	76,500	56.2	17.8	54.5	292	46.4

*B 15 broke outside of punch-marks.

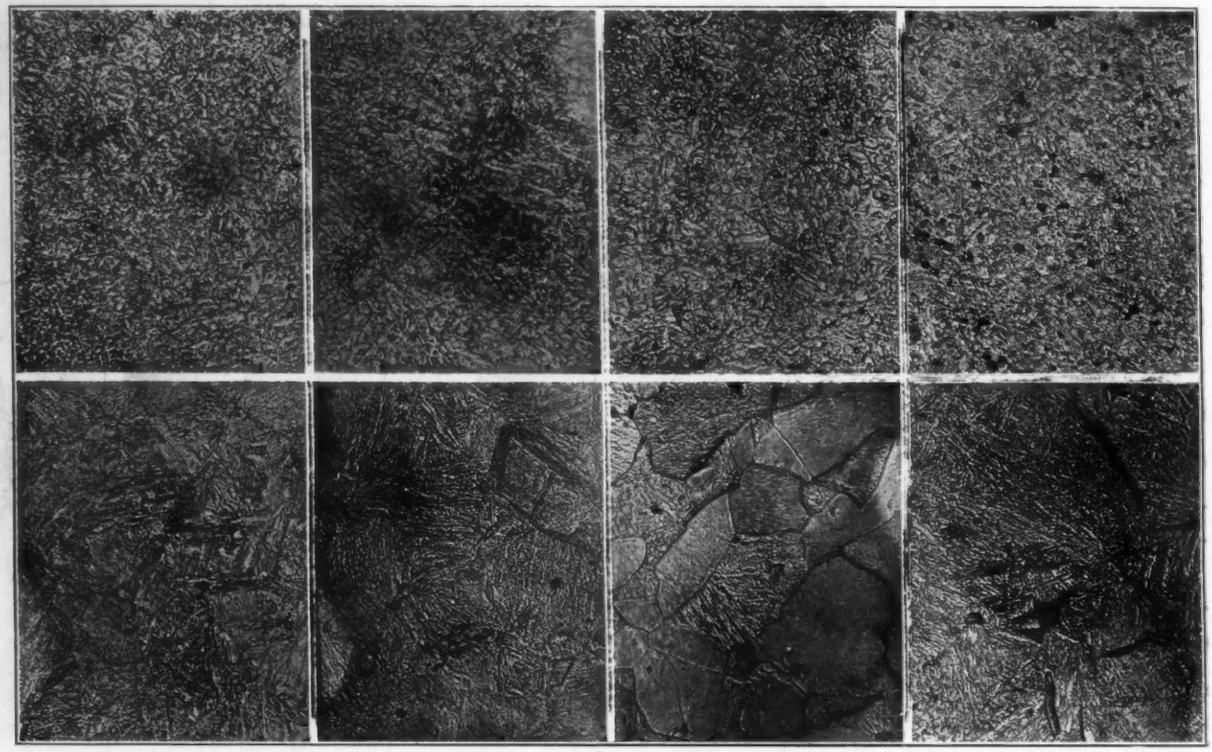
†These two specimens broke at the shoulder. They were repulled for tensile strength, elongation and reduction. B 16 broke outside of punch-marks.

TABLE 3.—COMPARISON OF THE TENSILE PROPERTIES OF HIGH-CHROMIUM STEEL* AFTER AIR, OIL AND WATER HARDENING.†

Hardening Medium	Tempering Temperature, deg. fahr.	Elastic Limit, lb. per sq. in.	Tensile Strength, lb. per sq. in.	Elongation in 2 in., per cent	Reduction in Area per cent	Diameter Impression, mm.
Air	932	158,800	192,400	13.0	40.5	3.12
Oil		163,100	202,700	8.0	18.2	3.10
Water		158,800	202,000	12.0	34.2	3.10
Air	1112	99,700	120,100	21.0	59.2	3.90
Oil		88,300	116,500	20.0	56.9	3.90
Water		90,300	120,700	22.0	59.8	3.87
Air	1292	70,800	101,200	26.0	64.6	4.25
Oil		78,000	105,500	25.5	63.8	4.07
Water		66,100	102,600	25.8	64.7	4.10
Air	1382	66,100	98,300	28.0	63.6	4.25
Oil		88,300	98,800	27.0	66.3	4.20
Water		67,200	97,900	27.0	65.2	4.22

*Composition of steel: Carbon, 0.30 per cent; Manganese, 0.40 per cent; Chromium, 13.00 per cent.

†The tests were made on a standard English test-bar and the strength values are given to the nearest 100 lb. The quenching temperature was 1607 deg. fahr. in all cases and the time of tempering was 1 hr.



A 1	A 2	A 3	A 4
1562	1652	1750	1850
A 5	**A 6**	**A6**	**A 7**
1950	2100	2100	2250

FIG. 9—MICROGRAPHS OF QUENCHED HIGH-CHROMIUM STEEL

The Figures under Each Specimen Indicate the Temperature in Degrees Fahrenheit at Which It Was Quenched in Oil. The Magnification Is 250 Times. The Second Specimen A 6 Represents a Small Portion of the Cross-Section.

and tempered at various temperatures between 400 and 1235 deg. fahr. (206 and 668 deg. cent.) shows similar features as illustrated in Fig. 10. Samples quenched from the lower temperature show a partial precipitation of the carbide, while those first quenched from the higher heat are practically free from this constituent until tempered at 1000 deg. fahr. (538 deg. cent.) or above, but show evidence of the retention of the polyhedral grain boundaries even when tempered at the higher tempering temperatures used.

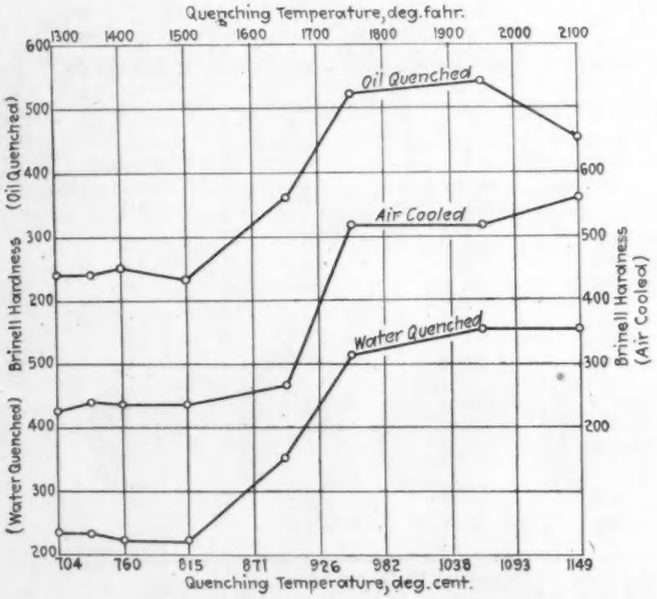


FIG. 8—HARDNESS OF QUENCHED HIGH-CHROMIUM STEEL

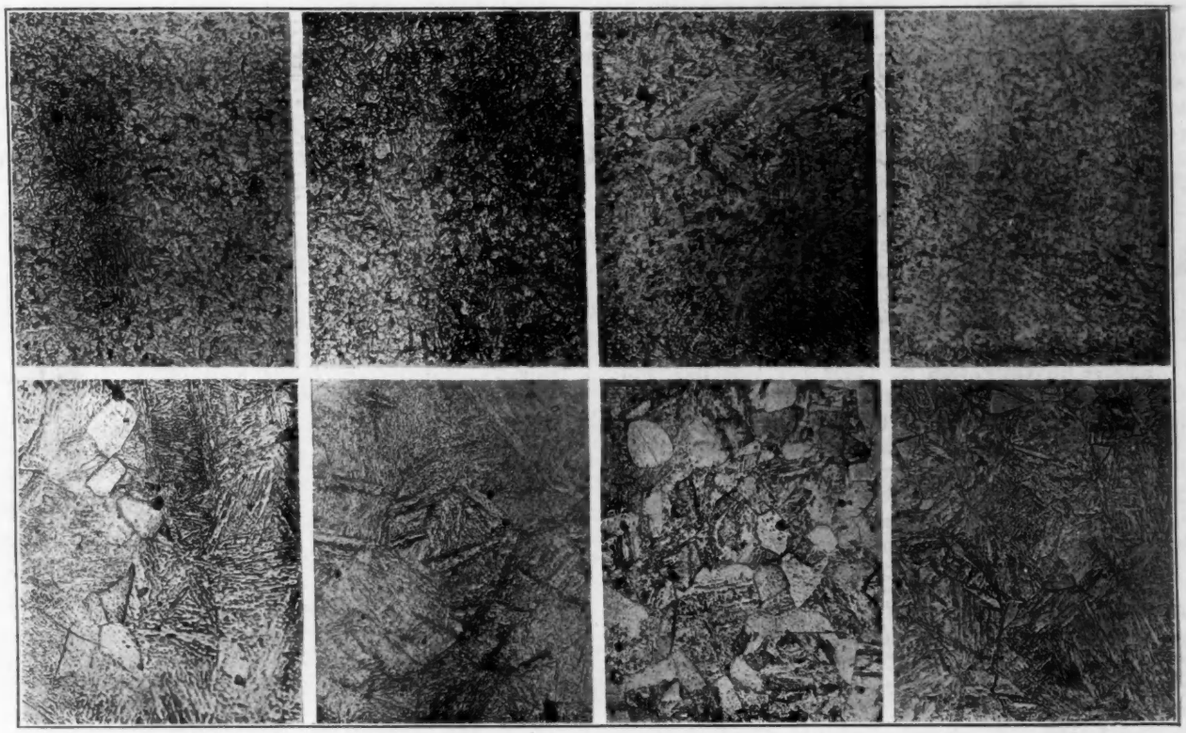
It is interesting to note that the structures obtained in quenching generally persist even at tempering temperatures fairly close to the critical ranges, a phenomenon which is undoubtedly directly associated with the special properties of this steel.

SUMMARY

Samples of a high-chromium steel quenched in oil from various temperatures show that:

(1) With an increasing quenching temperature the hardness as measured by the Brinell and Shore instruments increases until a temperature of about 1950 deg. fahr. (1066 deg. cent.) is reached. The maximum range of hardness is generally obtained by quenching from this temperature up to the highest heat used, but in some cases this hardness actually decreases to a retention of the solid solution

(2) Quenching from about 1750 deg. fahr. (955 deg. cent.) developes the best combination of strength and ductility, which is not coincident with the range of maximum hardness. Quenching from this or lower temperatures does not retain all the carbide in solution, as is the case in the samples



A 11	A 12	A 13	A 14
1750	1750	1750	1750
400	815	1000	1235
A 15	**A 16**	**A 17**	**A 18**
2100	2100	2100	2100
400	815	1000	1235

FIG. 10—MICROGRAPHS OF QUENCHED AND TEMPERED HIGH-CHROMIUM STEEL

The Upper Figure under Each Specimen Indicates the Temperature in Degrees Fahrenheit at Which It Was Quenched in Oil and the Lower Is That at Which It Was Tempered for 30 Min. The Magnification in Each Case Is 250 Times.

quenched from considerably higher temperatures, notably 2100 and 2250 deg. fahr. (1149 and 1232 deg. cent.)

(3) Ductility as measured by the elongation and the reduction in area is very low in those samples quenched from 1850 deg. fahr. (1010 deg. cent.) or above

Short-time tempering at temperatures up to about 800 deg. fahr. (427 deg. cent.) of samples previously quenched from both 1750 deg. fahr. (955 deg. cent.) and 2100 deg. fahr. (1149 deg. cent.) decreases brittleness. However, ductility is increased to a greater extent in those samples quenched from 1750 deg. fahr. (955 deg. cent.) than in those quenched from the higher temperature. Tempering above about 800 deg. fahr. (427 deg. cent.) markedly decreases the strength values and the hardness, which is of course accompanied by a greatly increased ductility.

In general the structure of the hardened steel tends to persist even when tempered for a short period of time at temperatures comparatively close to the lower critical range, the characteristics depending upon the quenching temperature used. The most rapid change in the tensile properties and hardness occurs in tempering between about 800 and 1000 deg. fahr. (427 and 538 deg. cent.).

FALSE LIFT IN FREE BALLOONING

IN an Army spherical balloon flight from Bolling Field a few weeks ago, on the outskirts of Washington, the craft made a sudden drop into dense woods, giving the passengers a thrill they had little expected. This was due to the change in temperature between forests and the hot city streets, which is termed false lift in balloon vernacular. In free ballooning the effect is quite startling when experienced for the first time. The passengers crouching in the bottom of the basket are sure that something terrible is going to happen. The tree tops rush up past the basket with startling velocity. With great relief the aeronauts feel the momentum gently checked on the lower branches. An instant later the aircraft bounds a thousand feet in the air, causing a shower of leaves and small twigs and carrying a few small branches as souvenirs of its sudden and unexpected contact with the trees.—Air Service News Letter.

GOVERNMENT TOPOGRAPHIC MAPPING

CONRAD H. YOUNG has been appointed by President Vincent to represent the Society on the Advisory Council of the United States Board of Surveys and Maps. The Board is undertaking to coordinate the mapping efforts of various Government departments and bureaus, one main purpose being to facilitate the completion of a suitable official topographic map of the United States that can be used by the Government and by private individuals.

A Comparison of Hecter Fuel with Export Aviation Gasoline[1]

AVIATION engine developments for attaining higher power at altitude are following two principal lines, supercharging and an increase in the compression ratio. For the latter, fuels have been demanded which are capable of operating under compressions too high for gasoline. The Bureau of Mines in a comprehensive investigation of fuels for internal combustion engines, found cyclohexane mixtures to possess properties which led them to develop the hecter fuel. The ability of this fuel to withstand high compression without knock was demonstrated in an experimental engine at ground level and its general usability was proved by actual flight tests. It was accordingly submitted to the Bureau of Standards for comparison with export aviation gasoline as to power producing ability and fuel consumption when used in an engine with a 7.2 compression ratio.

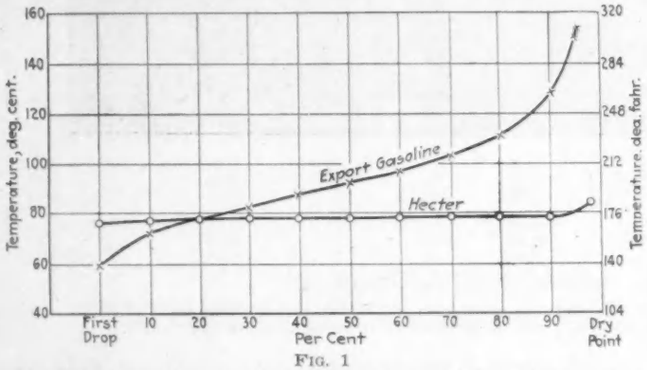


FIG. 1

The gasoline used in the tests was the standard reference fuel of the Bureau of Standards, known as X gasoline. It complies with specification No. 3512 of the Bureau of Aircraft Production for export aviation gasoline for the use of the A. E. F. 1918. The hecter fuel supplied for the tests was a mixture of approximately 30 per cent benzol and 70 per cent cyclohexane by volume. The properties of both fuels are shown in Fig. 1 and the accompanying table.

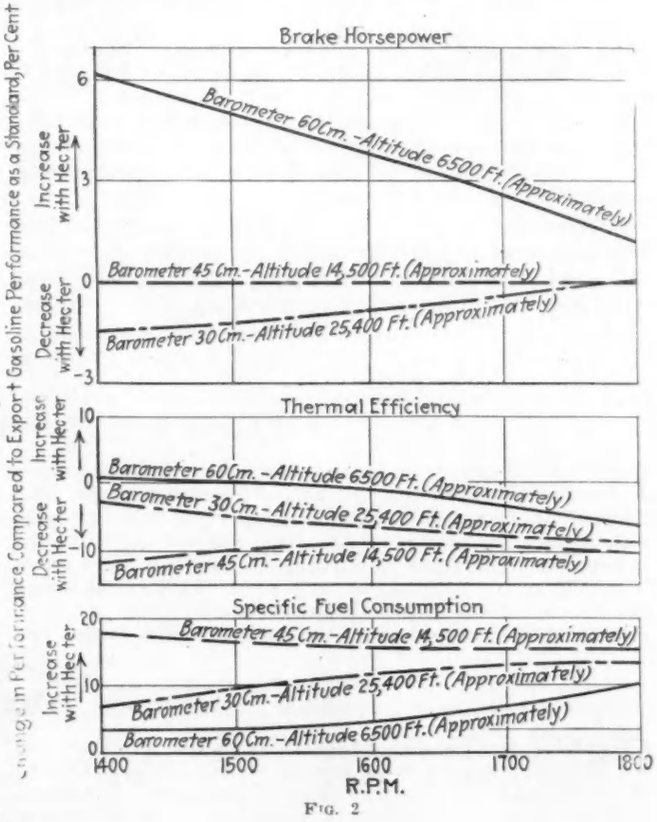
The fuels were tested in a twelve-cylinder Liberty airplane engine equipped with special pistons giving a compression ratio of 7.2. This ratio gave a measured compression pressure of 170 lb. per sq. in. gage. The engine was mounted in the altitude chamber of the Bureau of Standards automotive powerplants laboratory where controlled conditions of air pressure and temperature approximate those prevailing at altitudes up to 30,000 ft.

In these tests two fuel tanks were used, one containing the X gasoline, the other hecter. The engine was started on X gasoline and the desired conditions of speed and altitude reached with a comparatively rich mixture. The maximum torque having been attained, observations of torque were continued while the rate of gasoline supply was gradually reduced. The mixture was made leaner until the torque fell off considerably, and then gradually

Distillation	Hecter Fuel Temperature		X Gasoline	
	deg. cent.	deg. fahr.	deg. cent.	deg. fahr.
Initial boiling point	76	169	59	138
Per cent. 10	77	171	72	162
20	77	171	77	169
30	77	171	82	180
40	78	172	87	189
50	78	172	92	198
60	78	172	97	207
70	78	172	103	217
80	78	172	111	232
90	78	172	127	261
95	79	174	150	302
Dry point[2]	82	180	153	307

[2]98 per cent distillation for Hecter and 96 per cent for Gasoline.

enriched just enough to regain the maximum torque which had previously been noted. Readings were then taken of the various temperatures, pressures, torque, rates of flow and speed. The fuel supply from the X tank was then cut off and hecter supplied to the carbureter. After adjusting the carbureter for maximum torque with the least expenditure of fuel as described for


Brake Horsepower
Barometer 60 Cm. - Altitude 6500 Ft. (Approximately)
Barometer 45 Cm. - Altitude 14,500 Ft. (Approximately)
Barometer 30 Cm. - Altitude 25,400 Ft. (Approximately)
Increase with Hecter
Decrease with Hecter
Thermal Efficiency
Specific Fuel Consumption
Change in Performance Compared to Export Gasoline Performance as a Standard, Per Cent
R.P.M.
FIG. 2

[1]From an abstract of Report No. 89 of the National Advisory Committee for Aeronautics. Washington.

X gasoline, readings of test data again were made. By changing from one fuel to another in this manner, it is possible to eliminate effectually from the comparison of the fuels any effects due to changes in the condition of the engine.

The test results are shown graphically in Fig. 2, which is a performance comparison on a percentage basis, all results being plotted against altitude.

Conclusions

For flight at low altitudes hecter fuel showed slight advantages in comparison with gasoline by affording a small increase of power over that necessary to offset the disadvantage of increased fuel consumption. The usual ratio of fuel weight to plane weight is of the order of 1 to 7, so that for full-throttle flying an increased fuel consumption of 7 per cent balances an increase of 1 per cent in power developed. The test at 6500-ft. altitude showed that hecter fuel developed slightly more power than X gasoline, the maximum advantage being 7 per cent and the average for all speeds 4 per cent, whereas the increase in fuel consumption averaged 5 or 6 per cent. Since at 14,000 ft. and 25,000 ft. no appreciable difference in power was obtained, whereas the fuel consumption of hecter was greater to the extent of 15 per cent by weight, the advantage lies with X gasoline.

The large difference in densities of hecter fuel and X gasoline make the fuel comparisons by weight and by volume read differently, and care must be exercised to distinguish them. Upon reducing pounds per brake-horsepower-hour to pints per brake-horsepower-hour it is found that hecter consumption at ground is less by volume than and about equal to that of X gasoline at 25,000 ft.

One gallon of hecter contains nearly 9 per cent more heat units than the same quantity of X gasoline, and the brake thermal efficiency of the engine using hecter is about the same percentage less than when using X gasoline. Thus the same tank full of either fuel would supply a plane with about the same available energy. Any part of a flight at very low altitude might be accomplished at a slightly higher plane speed with the hecter than with gasoline, as a consequence of the power characteristics described above.

It has been claimed that a high-compression engine has a greater factor of safety when operated with hecter fuel than with gasoline. The engine was not operated for a sufficient period of time to ascertain whether engine deterioration was more rapid with the 7.2 compression ratio than would be expected from experience with the 5.6 compression ratio. Consequently no comparison can be made of the effect of compression on fuels upon engine deterioration. However, since it is not generally considered advisable to operate an engine of this type with gasoline at a higher compression ratio than 5.6, it is of interest to compare the performance of a Liberty twelve-cylinder aviation engine of 5.6 compression ratio using gasoline, with the performance of the same type of engine with 7.2 compression ratio using hecter. Previous tests with this type of engine have shown that this change in compression produces about 10 per cent increase in power, with about the same percentage decrease in weight of fuel consumed per unit power. This change would be expected from a comparison of the "air standard" efficiencies. From these data it is concluded that hecter in a 7.2 compression ratio engine would produce about 10 per cent more power than would X gasoline in a 5.6 compression ratio, while using the same weight of fuel per unit power as for X gasoline in the lower compression.

ADDRESSES OF MEMBERS DESIRED

AT the present time the records of the Society do not contain the correct address of each of the members listed below. In every case communications sent to the last known business connection or mail address as it appears on the records has been returned to the New York office of the Society. Members who can supply information regarding the present location of these members or offer any suggestions as to where their correct addresses can be obtained will confer a favor upon the Society by communicating with the Secretary at the New York office. Any information that can be furnished will be a favor conferred upon the Society since it is only by the cooperation of the entire membership that the mailing list can be kept in an accurate condition and the members receive THE JOURNAL and other communications promptly.

ALLERTON, REUBEN
BARDO, J. B.
BARKER, GEORGE R.
BONNEY, W. L.
CHADBOURN, H. N., JR.
COCKRILL, FIRST-LIEUT. EMMETT
CROW, HAROLD I.
DURHAN, EDWARD, JR.
EAGLES, NELSON W.
FINDEISEN, RAYMOND
GREEN, L. P.
HARDING, HERBERT P.
JEFFREY, CAPT. MAX L.
JEROME, H. M.
KAIN, PETER
KERSHAW, G. D.
KIRKPATRICK, FIRST-LIEUT. ANDREW
KNAUER, C. H.
LATHROP, THOMAS L.
LEWIS, WILL I.
LIDDLE, FRANK E.
MCMILLAN, HORATIO G.
MILLER, JAMES A.
MILLS, CAPT. MARSHALL F.
OESCHGER, WALTER I.
OVERLOCK, R. F.
PECHNICK, FRANK J.
POWER, DONALD M.
ROBERTS, DAVID STEWART
ROSS, JAMES
SCHMIDT, HUGO F.
SHERWOOD, GEORGE W.
SINK, RUSSELL S.
STUCK, EVERETT
THEISEN, ALEX. J.
THOMPSON, HAROLD T.
TUCKER, GORDON E.
WALTON, HAROLD E.
WODEHOUSE, SERGT. B. A.

GENERIC NAME FOR INDUSTRIAL TRUCKS AND TRACTORS

IT was announced in the June issue of THE JOURNAL that a prize of $25 would be given for the best suggestion for a generic name covering industrial trucks and tractors. As a meeting of the Industrial Truck and Tractor Subdivision will be held early in September, all suggestions to be considered must be received at the Society office on or before Sept. 1. In case more than one member submits the name which is considered by the Subdivision to be the most descriptive, the amount of the prize will be given to each member.

The importance of deriving a generic name can be appreciated when it is considered that the term industrial truck or tractor may be applied equally well to motor trucks and farm tractors respectively. Industrial trucks and tractors are being used in increasing numbers at factories, freight terminals and railroad stations and at steamship docks. It will therefore be appreciated that a short name which can be used in referring to only these vehicles will be of great value not alone to those who use them but also to the builders.

PERSONAL NOTES OF THE MEMBERS

C. S. Ash, formerly chief engineer of the National Wire Wheel Works, Inc., Hagerstown, Md., has been made vice-president and general manager of a new organization, known as the Detroit Wheel Corporation, Detroit.

W. L. Berlinghof has severed his connection with the Eisemann Magneto Corporation, Brooklyn, N. Y., to become vice-president and treasurer of the Pyramid Winding & Electric Corporation, of the same city.

O. C. Berquist, formerly in the engineering department of the Naval Aircraft Factory, Philadelphia, is now a salesman for the Equitable Life Assurance Society, in the same city.

Lloyd I. Birckelbaw is now doing drafting on experimental work for the Packard Motor Car Co., Detroit. He was formerly located at Fresno, Cal.

C. J. Blakeslee has resigned as manager of the Crane Tire Co., Davenport, Iowa, and has become manager of the Chicago Tire & Supply Co., 1720 South Michigan Avenue, Chicago.

F. K. Blanchard has resigned as engineer and general manager of the truck division of the Milburn Wagon Co., Toledo, Ohio, and has been appointed assistant engineer of the engine division of the Buda Co., Harvey, Ill.

M. H. Blank has opened an office at 1430 West Twenty-ninth Street, Cleveland, for the practice of consulting engineering. He was formerly automotive engineer at the Lynite Laboratories of the Aluminum Manufactures, Inc., also of that city.

Kenneth J. Boedecker has severed his connection with the Russel Motor Axle Co., North Detroit, Mich., and has accepted a position with the Oakland Motor Car Co., Pontiac, Mich.

A. H. Bowlzer, Jr., is now chief engineer in charge of production with the California Motor Car Corporation, Los Angeles. He formerly conducted the business of the Bowlzer Tire Service.

Maurice B. Brand, Jr., formerly a designing draftsman with the American Sleeve Valve Co., New York City, is now designing engineer with the Elbee Co., 128 East Forty-fifth Street, also of that city.

Robert W. A. Brewer has severed his connection with the Nordyke & Marmon Co., Indianapolis, and has become general manager of the Brewer Manifold Co., Dayton, Ohio.

A. C. Bryan now holds the office of vice-president of the Durston Gear Corporation, Syracuse, N. Y., in addition to that of factory manager. He was formerly chief engineer and factory manager.

C. A. Call, formerly general sales manager of the Federal Corporation, Westfield, Mass., has accepted a position with the Metal Saw & Machine Co., Springfield, Mass.

Robert S. Campbell has severed his connection with the Pittsburgh Model Engine Co., Pittsburgh, and has accepted a position in the service department of the Standard Steel Car Co., of the same city.

J. G. Carroll, formerly general engineer of the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., is now chief engineer of the Walker Vehicle Co., Chicago.

Herbert Chase has accepted a position as engineer with the Trent Process Corporation, 1440 U Street, Northwest, Washington. He was formerly connected with the Power Plants Corporation of that city.

W. P. Chrysler has become executive vice-president and general manager of the Willys-Overland Co., with offices at 52 Vanderbilt Avenue, New York City. He was formerly first vice-president of the General Motors Corporation, Detroit.

H. D. Church has become vice-president in charge of engineering development of Hare's Motors, Inc., Bridgeport, Conn. He was formerly vice-president of the Mercer Motors Co., Trenton, N. J.

W. H. Conant, formerly president of the Prismolite Co., Columbus, Ohio, is now president of the Hardware Products Co. of that city.

E. J. Cook has resigned as chief engineer with the Wisconsin Parts Co., Oshkosh, Wis., to accept a position with the Chicago Standard Axle Co., Chicago.

Willis D. Cook, formerly of Benicia, Cal., has become vice-president and chief engineer of the Henneuse Tractor Co., Sacramento, Cal.

J. F. Coyle has accepted a position in the engineering department of the Pratt & Whitney Co., Hartford, Conn. He was formerly a machine designer with the Sprague Canning Machinery Co., Hoopeston, Ill.

M. E. Crow is no longer vice-president of the Crow-Elkhart Motor Corporation, Elkhart, Ind., but holds the same office in the Marathon Motors Export Co., in the same city.

William P. Crowell is now connected with the Overland Nebraska Co., Norfolk, Neb. He was formerly assistant mechanical engineer in the Bureau of Standards, Washington.

William W. Dean is now electrical engineer for the United States Cartridge Co., Lowell, Mass. He formerly held the same position with the Engineering Laboratories, Chicago.

Albert W. De Chard has severed his connection with the Aeromarine Plane & Motor Co., Keyport, N. J., and is now aeronautical designer with the Ordnance Engineering Corporation, Baldwin, N. Y.

Clyde E. Dickey has been elected first vice-president and general manager of the Hammond Steel Co., Inc., Syracuse, N. Y. He was formerly president of the Dickey Steel Co., Inc., New York City, the Eastern sales and export representative of the Hammond organization.

D. W. Douglas has resigned as chief engineer of the Glenn L. Martin Co., Cleveland. He has not accepted another position as yet.

W. D. Drysdale has severed his connection with the Willys-Overland Motor Car Co., Toledo, and has organized the Drysdale Engineering Co., 650 Woodward Avenue, Detroit.

E. Paul duPont is president of duPont Motors, Inc., Wilmington, Del., the organization which has taken over the duPont Motor Mfg. Co. and the Delaware Marine Motor Co.

Dane L. Edwards has accepted a position in the metallurgical department of the Samson Tractor Co., Janesville, Wis., He was formerly laboratory superintendent of the Wyeth Chemical Co., Detroit.

A. M. Elliott has become factory manager of the Western Rubber Co., South Tacoma, Wash. He formerly held the same position at the McGraw Tire & Rubber Co., East Palestine, Ohio.

Paul H. Engel has accepted a position as chief engineer with the Good Inventions Co., Brooklyn, N. Y. During the war he was an engineer in the Ordnance Department with the rank of first lieutenant.

W. E. England has accepted the position of chief engineer of the F. B. Stearns Co., Cleveland. He formerly occupied a similar position with the Root & Vandervoort Engineering Co., East Moline, Ill.

Thomas Webster Farnsworth is now in the production department of the Hartford Machine Screw Co., Hartford, Conn. For fourteen months he was located in Constantinople, Turkey, as director of the motor transportation unit of the Near East Relief.

E. Favary left for Italy on June 8. He will go through Naples, Rome, Florence, Venice, thence to Bucharest. On his return trip he will stop in Zurich, Paris and possibly touch England and leave France on Sept. 6.

N. O. Fulton has returned to Scotland after an extended tour of this country, in which he visited a number of the leading automobile factories.

Ralph C. Garland, who for the past four years has been in the engineering department of the General Motors Corporation, Detroit, has joined the Wisconsin Parts Co., Oshkosh, Wis., as chief engineer. He will have charge of a large

experimental laboratory which the Wisconsin company is planning to install.

H. H. Gildner has become corporation sales manager of the Overman Cushion Tire Co., 250 West Fifty-fourth Street, New York City. He was formerly vice-president of F. R. Blair & Co., 50 Church Street, that city.

Christian Girl, formerly of Cleveland, has become president of the Kalamazoo Spring & Axle Co., Kalamazoo, Mich.

Edgar S. Gorrell has accepted the position of sales extension manager with the Nordyke & Marmon Co., Indianapolis. He was a colonel in the Air Service during the war.

C. D. Hanscom has become chief engineer of the Glenn L. Martin Co., Cleveland.

J. R. Harbeck, vice-president of the American Can Co., New York City, has been elected a director of the Willys-Overland Co., Toledo, Ohio.

Frank S. Hart is affiliated with the Packard Motor Car Co., Detroit. He was an automotive engineer in the Motor Transport Corps, with the rank of lieutenant.

F. D. Howe, who was formerly chief engineer of motor trucks with the International Harvester Corporation, Chicago, has accepted the position of director of engineering with the Thomart Motor Co., Kent, Ohio.

O. E. Hunt has been made vice-president of the Locomobile Co., Bridgeport, Conn. He formerly held the same office in the Mercer Motors Co., Trenton, N. J.

James R. Irvine, formerly draftsman with the Holt Mfg. Co., Stockton, Cal., has accepted a position in the same capacity with the Celite Products Co., Lompoc, Cal.

S. S. Jenkins, for the past eight years district manager of the Willard Storage Battery Co. at Indianapolis and Detroit, has joined the staff of the Bijur Motor Appliance Co., Hoboken, N. J., in the capacity of district manager at Detroit.

V. C. Kloepper has resigned his position as chief engineer with the Astra Motors Corporation, St. Louis.

B. G. Koether, who was recently elected vice-president of the Hyatt Roller Bearing Co., Harrison, N. J., has been made assistant general manager. While he still remains a vice-president of the organization, he will in the future be engaged in increasing production instead of having charge of the sales and advertising work.

Emil Kraemer has joined the engineering staff of the Timken Roller Bearing Co., Canton, Ohio, as mechanical engineer. He was formerly designing engineer with A. J. Slade, New York City.

H. D. Kramm is now president of the Maluminum Castings Co., Indianapolis. He was formerly manager of the Kramm Foundry Co., which was reorganized on April 1 with increased capitalization under the name of the former company.

D. A. Kratzer has severed his connection with the Bureau of Standards, Washington, and is now connected with the Missouri Valley Bridge & Iron Co., Leavenworth, Kan.

George L. LaBar, formerly with the Premier Motor Corporation, Indianapolis, is now routing engineer with the Canadian Products, Ltd., Walkerville, Ont., Canada.

Nathan L. Lieberman has become general manager of the New Jersey Brass Foundry, Bayonne, N. J. He was formerly connected with the Curtiss Engineering Corporation, Garden City, N. Y.

William W. Linden, formerly of Indiana Harbor, Ind., has opened a garage at Brentford, S. D.

William F. McCarthy has resigned as chief engineer of the Defiance Machine Works, Defiance, Ohio, and has been elected president and treasurer of the Progressive Engineering & Sales Co., 316 Wedgewood Building, Toledo, Ohio.

Alden L. McMurtry is now consulting engineer for the Motor Vehicle Department of the State of Connecticut, located at Hartford.

M. S. McNay, formerly sales engineer with the Standard Parts Co., Cleveland, is now connected with the Bock Bearing Co., Toledo, Ohio.

H. W. Merritt has returned to the employ of the Duplex Engine Governor Co., 36 Flatbush Avenue Extension, Brooklyn, N. Y. He was recently engineer and technical consultant with William H. Orpen, New York City.

C. L. Moody has severed his connection with the Perfection Tire & Rubber Co., Fort Madison, Iowa, and is now associated with the Fisk Rubber Co., Chicopee Falls, Mass.

Edmund Quincy Moses is engaged in the practice of law at 165 Broadway, New York City, as a member of the firm of Moses, Hammond & Middleton. His specialty is patent laws.

J. J. Murray, designer of the Murray-Willat Motor & Aeroplane Corporation, has moved his office from New York City to Los Angeles, Cal.

Cornelius T. Myers has transferred his office from Avenal, N. J., where he carried on work for the Air Service and the Ordnance Department, to Rahway, N. J. He is located in the Rahway National Bank at that city and expects to open an office at New York City at an early date.

Nelson B. Nelson has severed his connection with the J. I. Case Threshing Machine Co., Racine, Wis., as assistant engineer and is now associated with the Kardell Tractor & Truck Co., St. Louis, in the capacity of superintendent and chief engineer.

Harold Nutt, formerly engineer and designer in the railway motor car department of Fairbanks, Morse & Co., Three Rivers, Mich., has become automotive engineer with the Premier Motor Corporation, Indianapolis.

Carl Francis Ogren has opened an office at 149 Broadway, New York City, as mechanical engineer. He was formerly plant engineer with the American Bronze Corporation, New York City.

W. A. Parrish, formerly a consulting engineer at Akron, Ohio, has accepted a position as chief engineer with the Thomart Motor Co., Kent, Ohio.

A. E. Patchin has been elected president of the Consumers Service Co., South Bend, Ind. He was formerly general sales manager of the Dependable Truck & Tractor Co., Galesburg, Ill.

William John Pearmain has been appointed experimental engineer of the Wallis Tractor Division of the J. I. Case Plow Works Co., Racine, Wis. He was formerly assistant chief engineer of the company.

Jost W. Petrie is connected with the Commonwealth Heat Treating Co., 700 Commonwealth Avenue, Detroit. He was formerly metallurgist of the Kelvinator Corporation of the same city.

Glendon M. Pomeroy, formerly mechanical engineer with the United Aircraft Engineering Corporation, New York City, is now sales manager of the Matthews Mfg. Co., Worcester, Mass.

John W. Powelson has become president and general manager of the Powelson Foundry & Machine Co., Rochester, N. Y. He was formerly works manager of the Pittsburgh Model Engine Co., Pittsburgh.

N. S. Reed has resigned as truck engineer of the Paige-Detroit Motor Car Co., Detroit, to accept the position of consulting engineer of the sales division with the Hinkley Motors Corporation, also of that city.

Harold G. Rendall has severed his connection with the Mitchell Motors Co., Racine, Wis., and become designing engineer with the Winther Motor Truck Co., Kenosha, Wis.

Gustave F. Richardson has severed his connection with Marburg Brothers, Inc., New York City, and is conducting a business for the repair and sale of ignition, starting and lighting apparatus under his name at 1740 Cornelia Street, Brooklyn, N. Y.

Grahame B. Ridley, formerly dynamometer engineer with Hall-Scott Motor Car Co., Berkeley, Cal., has become engineer in the laboratory of Heineman-Pearson Co., 520 Rialto Building, San Francisco.

Edward K. Roberts, formerly sales manager of the Bush

Mfg. Co., Hartford, Conn., has become general sales manager of the Stewart Motor Corporation, Buffalo.

M. H. Roberts has severed his connection as chief engineer with the Air Reduction Co., New York City, to accept a similar position with the Franklin Railway Supply Co., 30 Church Street, of that city.

Delmar G. Roos has resigned his position as chassis engineer of the Hare's Motors, Inc., Bridgeport, Conn., to accept a position with Gaston, Williams & Wigmore, Inc., 39 Broadway, New York City.

E. A. Ross, formerly head of department, Motor Transport Training School, Camp Holabird, Baltimore, Md., has become secretary of the Potter-Casey Co., Aitkin, Minn.

Richard F. Russell is now works manager of the Raymond Engineering Co., 309 Lafayette Street, New York City. He was formerly assistant chief engineer of the Air Reduction Co., New York City.

James W. Schiller has accepted a position with the Olds Motor Works, Lansing, Mich. He was formerly connected with the Northway Motor & Mfg. Co., Detroit.

W. A. Schuehle has accepted a position with Canadian Products, Ltd., Walkerville, Ont., Canada. He was formerly consulting engineer in the armament department, Bureau of Aircraft Production, and was stationed at McCook Field, Dayton, Ohio.

L. F. Seaton has assumed the duties of chief engineer in connection with those of production manager of the Patriot Motors Co., Lincoln, Neb., which was formerly known as the Hebb Motors Co.

Edwin M. Smith has severed his connection with the Pittsburgh Model Engine Co., Pittsburgh, and is now consulting engineer of the Kilbourne & Jacobs Mfg. Co., Columbus, Ohio.

R. Leon Smith has accepted a position as designer with Samson Tractor Co., Janesville, Wis. He was formerly a designer in the Artillery Tractor Experimental Shop, Ordnance Department, Detroit.

Hubbard W. Steiner, formerly assistant engineer at the American axle plant of the Standard Parts Co., Cleveland, has accepted a position as chief engineer of the Trailmobile Co., Cincinnati.

W. R. Stewart, formerly chief instructor in the automotive department of the Pittsburgh Business College, Pittsburgh, Kan., has accepted a position with the Bluff City Electric Co., Memphis, Tenn.

O. E. Szekely, president of the O. E. Szekely Co., announces the removal of the company's offices and experimental station from the Safety Building, Rock Island, Ill., to 1516 Fourth Avenue, Moline Ill.

Michael E. Toepel has resigned as technical service engineer with the Splitdorf Electrical Co., Newark, N. J., and has accepted a position as assistant electrical engineer with the International Motor Co., Sixty-fourth Street and West End Avenue, New York City.

S. G. Tresouthick is connected with the Ilg Electric Ventilating Co., 13 Park Row, New York City, as sales engineer.

J. G. Utz, formerly engineering supervisor of the Standard Parts Co., Cleveland, is now engaged in the business of advisory engineer at Detroit.

Paul C. Wagner, chief engineer with Blood Brothers Machine Co., Allegan, Mich., has accepted a position in the same capacity with the Four Drive Tractor Co., Big Rapids, Mich.

J. Russell Walsh has resigned from the combustion engineering department of the Bethlehem Steel Co., Bethlehem, Pa., and is now aeronautical mechanical engineer in the engineering division of the Air Service. He is stationed at McCook Field, Dayton, Ohio.

E. W. Weaver is engaged in the engineering business at 5103 Euclid Avenue, Cleveland, under the firm name of Weaver & Kemble.

Harrie R. Williams, formerly general manager and chief engineer of A. J. Picard & Co., New York City, is now consulting engineer for the Homer McKee Co., Kahn Building, Indianapolis.

George H. Woodfield has resigned his position as body engineer with the Milburn Wagon Co., Toledo, and has taken a similar position with the Hale & Kilburn Corporation, Philadelphia.

Evan H. Wright now holds the position of mechanical engineer in the Stout Engineering Laboratories, Detroit. He was formerly aeronautical engineer in the Detroit office of the United Aircraft Engineering Corporation, New York City.

Charles R. Yous has accepted a position as superintendent of the used car repair shop of the Marmon Chicago Co., 2430 Michigan Avenue, Chicago.

OBITUARY

C. H. GURNETT died at the Englewood Union Hospital, May 11, following an operation for acute appendicitis which was performed about two weeks earlier. He was born at Ingersoll, Ont., Canada, July 24, 1866, and came to Chicago at the age of 16. He first entered the employ of the A. F. Barnes Co., book publisher, remaining there until the company was merged with the American Book Co. In 1901, having purchased an interest in the *Automobile Review*, he left the American Book Co. and for the next two years he was part owner and publisher of that periodical, becoming associated with *The Automobile* in 1903. Mr. Gurnett was appointed Western advertising manager for the Class Journal Co., when that organization purchased *Motor Age* and *Motor World*, and continued to hold that position until his death. He is survived by his widow and six children. Mr. Gurnett was elected to Associate Member grade in the Society, April 10, 1919.

FOREIGN AIR ROUTES

IN 1919 three air routes were established and operated in France, apart from irregular flights. These were between Paris and London, Paris and Lille, and Toulouse and Rabat, Morocco. The Under-Secretary for Aviation is planning a wide network of air routes across France and to African colonies, as well as to England, Spain and Italy.

NATIONAL TRANSPORTATION

FOOD, minerals and merchandise must be transported in this country over approximately 240 miles of airways, 15,000 miles of inland waterways, 350,000 miles of railways and 2,500,000 miles of highways. One-fourth of 1 per cent of this 2,500,000 miles of highways is suitable for motor trucks.

Numerous food producers, now engaged in the transportation and distribution of foodstuffs in small quantities, could be economically replaced by parcel post service. Sixty thousand parcel post carriers daily traverse 1,400,000 miles of highways through producing territory. If each transported 2000 lb., the amount would feed approximately 40,000,000 people. Why do not they do it? There are three obstacles; first, the highways are not suitable; second, the vehicles not suitable, and third, high postage rates.—Fourth Assistant Postmaster General Blakeslee.

1919 MOTOR-VEHICLE PRODUCTION

UNOFFICIAL figures compiled from various sources indicate that in the year ended Dec. 31, 1919, ninety manufacturers of passenger cars and 170 builders of motor trucks situated in thirty-two States and employing 580,000 persons produced approximately 1,586,787 passenger cars and 305,142 motor trucks. The total value of the output was $1,807,593,829.

Applicants *for* Membership

The applications for membership received between May 26 and June 14, 1920, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

BAENDER, FRED G., professor of heat power engineering and superintendent of mechanics arts, University of Arkansas, *Fayetteville, Ark.*

BALDY, HURLEY, JR., assistant chief engineer, Quaker City Corporation, *Philadelphia.*

BOWERMAN, J. A., assistant general production superintendent, Fisk Rubber Co., *Chicopee Falls, Mass.*

BUCK, PORTER A., chief draftsman, Detroit Transmission Co., *Detroit.*

BUDERUS, W. H., automotive engineer, Vacuum Oil Co., *Chicago.*

CRAWFORD, DAVID FRANCIS, president, Westinghouse Union Battery Co., *Swissvale, Pa.*

CREEHOSKI, JOSEPH V., factory layout and plant engineer, Charms Co., *Newark, N. J.*

CRONSTEDT, VALDEMAR N., aeronautical mechanical engineer, Commercial Truck Co., *Philadelphia.*

CUMMINS, C. L., president and general manager, Cummins Engine Co., *Columbus, Ind.*

DEWEESE, BERNARD D., sales engineer, Columbia Axle Co., *Cleveland.*

DOHNER, BURT E., secretary and treasurer, Ohio Metal Products Co., *Dayton, Ohio.*

DOHNER, JOHN H., president and manager, Ohio Metal Products Co., *Dayton, Ohio.*

EASTON, J. A. G., engineer and manager, Aircraft Materials & Equipment Corporation, *New York City.*

FARMER, A. M., industrial engineer, L. V. Estes, Inc., *Chicago.*

FENTON, DANIEL H., head of tire testing department, Fisk Rubber Co., *Chicopee Falls, Mass.*

FLETCHER, V. H., designing engineer, Gray Motor Co., *Detroit.*

FORTIER, A. D., salesman, Coe-Stapley Mfg. Corporation, *West Haven, Conn.*

FRY, H. DELONG, importer and exporter, H. DeLong Fry & Co., *New York City.*

GARDNER, GILBERT M., aeronautical mechanical engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio.*

GASTINEAU, G. A., manager of technical division, Hupp Motor Car Corporation, *Detroit.*

GOSCHE, KARL W., chemical engineer, Westinghouse Union Battery Co., *Swissvale, Pa.*

GRAY, C. C., engineer, American Harvester Co., *Minneapolis, Minn.*

GUILD, THOMAS A., manager of sales, Westinghouse Union Battery Co., *Swissvale, Pa.*

HAITZ, FRED, JR., student, Iowa State College, *Ames, Iowa.*

HAWES, COL. GEORGE P., JR., United States Army, *Camp Holabird, Md.*

HEATH, LEE M., draftsman, Chevrolet Motor Co., *New York City.*

HEATH, LEWIS W., general manager, Litscher Lite Corporation, *Grand Rapids, Mich.*

HEINEMANN, J. A., chief engineer, Dragon Motors Corporation, *Chicago.*

HEINISH, GEORGE, draftsman, Paragon Motor Car Co., *Cleveland.*

HENDRICKS, R. G., factory superintendent, Graham Bros., *Evansville, Ind.*

HERR, JAMES H., aeronautical mechanical engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio.*

HERTZLER, ARTHUR G., sales and purchase engineer, Bearings Co. of America, *Lancaster, Pa.*

HOLCOMB, WALTER W., garage manager, Fisk Rubber Co., *Chicopee Falls, Mass.*

HOOD, P. W., sales manager, Timken-Detroit Axle Co., *Detroit.*

HORNER, FREDERICK C., transportation engineer, Packard Motor Car Co. of New York, *New York City.*

HUBACH, GUSTAVE, mold equipment engineer, Fisk Rubber Co., *Chicopee Falls, Mass.*

IRODELL, ROBERT, chief engineer, General Tire & Rubber Co., *Akron, Ohio.*

JACOBI, EDWARD, chief engineer, Briggs & Stratton Co., *Milwaukee.*

JONES, LOUIS R., engineer, Peters Machine & Mfg. Co., *Cleveland.*

JOSEPH, LAWRENCE E., sales engineer, Snead & Co. Iron Works, *Jersey City, N. J.*

KAHN, WILLIAM FRED., electrical superintendent, Luthy Battery Co., *San Francisco.*

KEAN, JOHN SCOTT, aeronautical draftsman, League Island Navy Yard, *Philadelphia.*

KELLY, R. C., engineer, Root & Van Dervoort Engineering Co., *East Moline, Ill.*

KLINE, CHARLES E., superintendent of assembly, Hahn Motor Truck & Wagon Co., *Hamburgh, Pa.*

LANGENHEIM, ALBERT H., chief draftsman, Eaton Axle Co., *Cleveland.*

LAURENT, M. P., designer and engineer, Fairbanks, Morse & Co., *Three Rivers, Mich.*

LIBBEY, JAMES T., sales engineer, Doehler Die-Casting Co., *Brooklyn, N. Y.*

LUCAND, ALEXANDER, designer, International Motor Co., *New York City.*

MADDEN, E. B., chief engineer, Comet Automobile Co., *Decatur, Ill.*

MALONE, ERWIN LIONEL, district representative, Hess Steel Corporation, *Baltimore.*

MARSH, L. BENNETT, purchasing engineer, Marsh Motor Car Co., *Cleveland.*

MASON, DALE R., general sales department, National Tube Co., *Pittsburgh.*

MERRILL, ALVIN, technical supervisor, American Brass Co., *Buffalo.*

NEAL, FRANKLIN G., patent attorney, Fisk Rubber Co., *Chicopee Falls, Mass.*

NEELY, E. HAROLD, sales engineer, Standard Steel & Bearings, Inc., *Philadelphia.*

NEWELL, FLOYD BELL, mechanical engineer, Bureau of Standards, *Washington.*

NORRIS, P. E., production engineer, Westinghouse Union Battery Co., *Swissvale, Pa.*

OLMSTED, E. F., sales director, Detroit Transmission Co., *Detroit.*

OSTERHOFF, EDMUND E., chief draftsman, National Motor Car & Vehicle Corporation, *Indianapolis.*

PALMGREN, CHARLES A., manager of works, Pittsburgh Model Engine Co., *Pittsburgh.*

PASMAN, JAMES S., designer, Sprague Electric Works, *Bloomfield, N. J.*

PLEXICO, ROBERT SPRATT, assistant engineer and draftsman, Anderson Motor Co., *Rock Hill, S. C.*

PUTNAM, W. P., president and general manager, Detroit Testing Laboratory, *Detroit.*

REISSER, HARRY, sales engineer, Link-Belt Co., *Indianapolis.*

RICE, FRED D., sales representative, Hess Steel Corporation, *Baltimore.*

ROLLER, WILLIAM F. C., draftsman, W. E. Quimby, Inc., *Newark, N. J.*

RONNING, ADOLPH, chief engineer, American Harvester Co., *Minneapolis, Minn.*

ROOT, DONALD C., sales engineer, Bridgeport Brass Co., *Bridgeport, Conn.*

RUNYAN, WILLIAM B., vice-president and general superintendent, Dayton Malleable Iron Co., *Dayton, Ohio.*

RYAN, THOMAS M., draftsman, Chevrolet Motor Co., *New York City.*

SANFORD, HAROLD M., consulting engineer, Stroud Motor Mfg. Association, Gunter Building, *San Antonio, Tex.*

SAXLOR, PARRY D., vice-president and general manager, Dunlop America, Ltd., *Buffalo.*

SCHULTZ, J. A., JR., assistant manager, Doehler Die-Castings Co., *Toledo, Ohio.*

SEMPLE, CHARLES C., chief engineer, Rochester Motors Corporation, *Rochester, N. Y.*

SKIFF, W. M., manager of engineering department, National Lamp Works of General Electric Co., *Cleveland.*

SOUTHMAYD, LEON N., manager of truck tire department, Fisk Rubber Co., *Chicopee Falls, Mass.*

SRIGLEY, WALLACE, designer, Canadian Products, Ltd., *Walkerville, Ont., Canada.*

STARR, C. E., general manager, Perfecto Gear Differential Co., *Bellingham, Wash.*

STEBBINS, HARRY YOUNG, engineer, Factory Perkun, *Warsaw, Poland.*

STERN, MARCUS, chief engineer, Doehler Die-Castings Co., *Toledo, Ohio.*

STEVENS, WILLIAM CLIFFORD, sales manager, Cutler-Hammer Mfg. Co., *Milwaukee.*

TAYLOR, E. C., patent attorney, Fisk Rubber Co., *Chicopee Falls, Mass.*

TEAGUE, NEWTON NESBITT, branch manager, H. B. Odell, Inc., *Augusta, Ga.*

THOMAS, BEN, experimental engineer, Cutler-Hammer Mfg. Co., *Milwaukee.*

THOMS, LANSING WILT, transportation engineer, Thomas J. Doyle Co., *Detroit.*

THROCKMORTON, GEORGE K., manager of isolated electric plant department, Sears-Roebuck & Co., *Chicago.*

TORRANCE, JAMES B., assistant professor, University of Minnesota, *St. Paul, Minn.*

TUNISON, M. C., consulting mechanical engineer, Tunison Products Co., *Oakland, Cal.*

WEINBERGER, HERMAN H., technical correspondent, General Motors Export Co., *New York City.*

WELLS, D. W., vice-president and general manager, Electric Steel & Forge Co., *Cleveland.*

WRIGHT, BERNARD F., chief engineer, Federal Motor Truck Co., *Detroit.*

YERAM, ZAKAR A., chief draftsman, Air Service, *Speedway, Ind.*

ZEDER, FRED M., chief engineer, Studebaker Corporation, *Detroit.*

ZIMMERMANN, WALTER V., service manager, Olds Motor Works, *Lansing, Mich.*

ZUMMACH, JOHN Z., chief engineer and assistant factory manager, Perfex Radiator Co., *Racine, Wis.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between May 14 and June 12, 1920. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (E S) Enrolled Student; (S M) Service Member; (F M) Foreign Member.

BIRCKELBAW, LLOYD I. (M) experimental drafting engineer, Packard Motor Car Co., *Detroit,* (mail) 29 Parsons Street.

BODENWIESER, ELIAS, JR. (A) Hudson Motor Car Co., *Detroit.*

BOOCK, ALFRED C. (J) draftsman, Pan Motor Co., *St. Cloud, Minn.,* (mail) 816 Seventh Avenue South.

BUREAU, ACHILLE G. (J) engineering department, Edward G. Budd Mfg. Co., *Philadelphia,* (mail) 2026 West Ontario Street.

CHAMBERLIN, DON M. (A) sales force, Detroit Pressed Steel Co., *Detroit,* (mail) 1329 Townsend Avenue.

CHAN, DIAM S. K. (E S) student, Purdue University, West Lafayette, Ind., (mail) c/o F. Chan, 4913 Grand Boulevard, *Chicago.*

CLARK, CHARLES S. (A) sales manager, H. J. Koehler Motors Corporation, *Bloomfield, N. J.,* (mail) 9 Winsor Place.

CONTOIS, ELY J. (A) tool engineer, Clark Equipment Co., *Buchanan, Mich.*

CRECELIUS, HENRY R. (M) body engineer, Hare's Motors, Inc., *Bridgeport, Conn.,* (mail) 850 Lafayette Street.

DEBRUN, FRANK H. (M) chief engineer, R. Mudge & Co., 4425 West Sixteenth Street, *Chicago.*

DEIN, GEORGE H. (M) chief engineer, National Snow Removal Corporation, New York City, (mail) 4169 Park Lane South, *Woodhaven, N. Y.*

DELONG, B. H. (M) metallurgical engineer, Carpenter Steel Co., *Reading, Pa.*

DONALDSON, O. M. (A) district manager, Briggs & Stratton, Milwaukee, (mail) 521 Guardian Building, *Cleveland.*

DOUGHERTY, E. FRED (J) draftsman, H. H. Franklin Mfg. Co., *Syracuse, N. Y.,* (mail) 119 Malcolm Street.

DUNHAM, CLIFFORD ANDERSON (A) district manager, B. F. Goodrich Rubber Co., Akron, Ohio, (mail) 2017 Euclid Avenue, *Cleveland.*

DUNN, WILLIAM C. (M) president and general manager, Ohio Crankshaft Co., *Cleveland,* (mail) 10517 Gooding Avenue.

FINCH, NATHANIEL A., JR. (M) supervisor of motor transportation, American Can Co., 120 Broadway, *New York City.*

FORD, F. LESLIE (J) chief draftsman, Cooley & Marvin Co., Boston, (mail) 21 Harvard Avenue, *Brookline, Mass.*

FORSBERG, UNO (M) vice-president, S. K. F. Administrative Co., 5 Nassau Street, *New York City.*

FRANCK, JOHN P. (A) sales manager, Guide Motor Lamp Mfg. Co., 11500 Madison Avenue, *Cleveland.*

FRASER, EDWARD SMITH (A) sales engineer, American Bosch Magneto Corporation, Detroit, (mail) Le Materiel Telephonique, 46 Avenue de Breteuil, *Paris, France.*

GALLOWAY, JAMES W. (J) designer, Smith, Hinchman & Grylls, *Detroit,* (mail) 1323 Trumbull Avenue.

GARGIULO, FREDERICK (A) president and treasurer, G & O Mfg. Co., 598 State Street, *New Haven, Conn.*

HAAS, LLOYD STEVENSON (M) engineer, Read Machinery Co., Inc., *York, Pa.,* (mail) P. O. Box 27.

HARRISON, EDWARD F. (A) owner and manager, Harrison Motor Car Co., 1726 Glenarm Street, *Denver.*

HEITZMAN, H. L. (A) secretary, Fedders Mfg. Co., Inc., 57 Tonawanda Street, *Buffalo.*

HODGES, SMITH L. (E S) student, Purdue University, West Lafayette, Ind., (mail) 3044 Ruckle Street, *Indianapolis.*

KAPLAN, MICHAEL J. (A) aeronautical draftsman, Naval Aircraft Factory, League Island Navy Yard, *Philadelphia,* (mail) 2417 North Eighteenth Street.

KENDALL, ALLEN (M) district manager, Hercules Motor Mfg. Co., Canton, Ohio, (mail) 1013 Peoples Gas Building, *Chicago.*

KNIGHT, MONTGOMERY (E S.) student, Massachusetts Institute of Technology, *Cambridge, Mass.,* (mail) 770 Massachusetts Avenue.

LARGE, FRANK EARL (M) engineer and second vice-president, Johnson Rim & Parts Co., Inc., 2519 Delaware Avenue, *Buffalo.*

LUMENT, GEORGES (M) director, Labatoire de l'Automobile Club de France, Boulevard Bourdon, 80, Neuilly, France, (mail) A2 rue Jose Maria de Heredia, *Paris, France.*

MCCAFFERTY, HAROLD J. (J) 1493 Bacon Road, *Akron, Ohio.*

MCLEOD, GEORGE D. (A) lubricating engineer, Sinclair Refining Co., 111 West Washington Street, *Chicago.*

MADISON KIPP CORPORATION (Aff) *Madison, Wis.* Representatives: Joseph A. Coleman, treasurer; T. A. Coleman, president; Thomas E. Coleman, vice-president; A. X. Merz, secretary.

MANSFIELD TIRE & RUBBER CO. (Aff) *Mansfield, Ohio.* Representatives: Warren E. Clark, mechanical engineer; Dr. K. J. Thompson, factory manager.

MARION TIRE & RUBBER CO. (Aff) *Marion, Ohio.* Representatives: R. D. Belden, superintendent; W. E. Cameron, sales manager; W. A. Patterson, factory manager.

MARTIN, J. F. JR. (J) tool designer, Lincoln Motor Co., West Warren Avenue, *Detroit,* (mail) 542 Putnam Avenue.

MATHEWS, VERNER P. (J) sales engineer, Perfection Spring Plant, Standard Parts Co., *Cleveland.*

NICKELSEN, JOHN M. (M) engineer, Buick Motor Co., *Flint, Mich.,* (mail) 506 Beach Street.

OWEN, LEROY (A) efficiency engineer, International Harvester Co., *Chicago,* (mail) 2402 South Ridgeway Avenue.

PLINKE, GEORGE WILLIAM (E S) student, Purdue University, West Lafayette, Ind., (mail) 1600 Beechwood Avenue, *Louisville, Ky.*

SCOTT, RALPH B. (J) layout draftsman, Winton Co., Cleveland, (mail) 1543 Woodward Avenue, *Lakewood.*

SMITH, J. P. (M) assistant manager of development department, Firestone Tire & Rubber Co., *Akron, Ohio.*

SMYTH, C. H. (A) sales engineer, Perfection Spring Plant, Standard Parts Co., East Sixty-fifth and Central Avenue, *Cleveland.*

STOUGH, CHARLES R. (J) chief draftsman, Hayes Wheel Co., *Jackson, Mich.*

STOUT, HENRY S. (A) 403 Dayton Savings Trust Building, *Dayton,* Ohio.

SWENSON, SWEN RANDOLPHE (J) chief engineer, radiator division, Marlin-Rockwell Corporation, *New Haven, Conn.*

THEISINGER, EARL FREDERIC (J) mechanical draftsman, Class Journal Publishing Co., New York City, (mail) 225 Greene Avenue, *Brooklyn, N. Y.*

TUBBS, FRED L. (M) vice-president, Alamo Farm Light Co., 703 Tower Building, *Chicago.*

WALDON, ELGIN POOLEY (E S) student, Purdue University, Lafayette, Ind., (mail) 244 West Grand Boulevard, *Detroit.*

WEST, W. C. (A) president, West & Dennett Co., 14 East Jackson Boulevard, *Chicago.*

WILLIAMS, JOHN M., JR. (M) engineer, 135 Montclair Avenue, *Montclair, N. J.*